ASTRONOMY

May 1979

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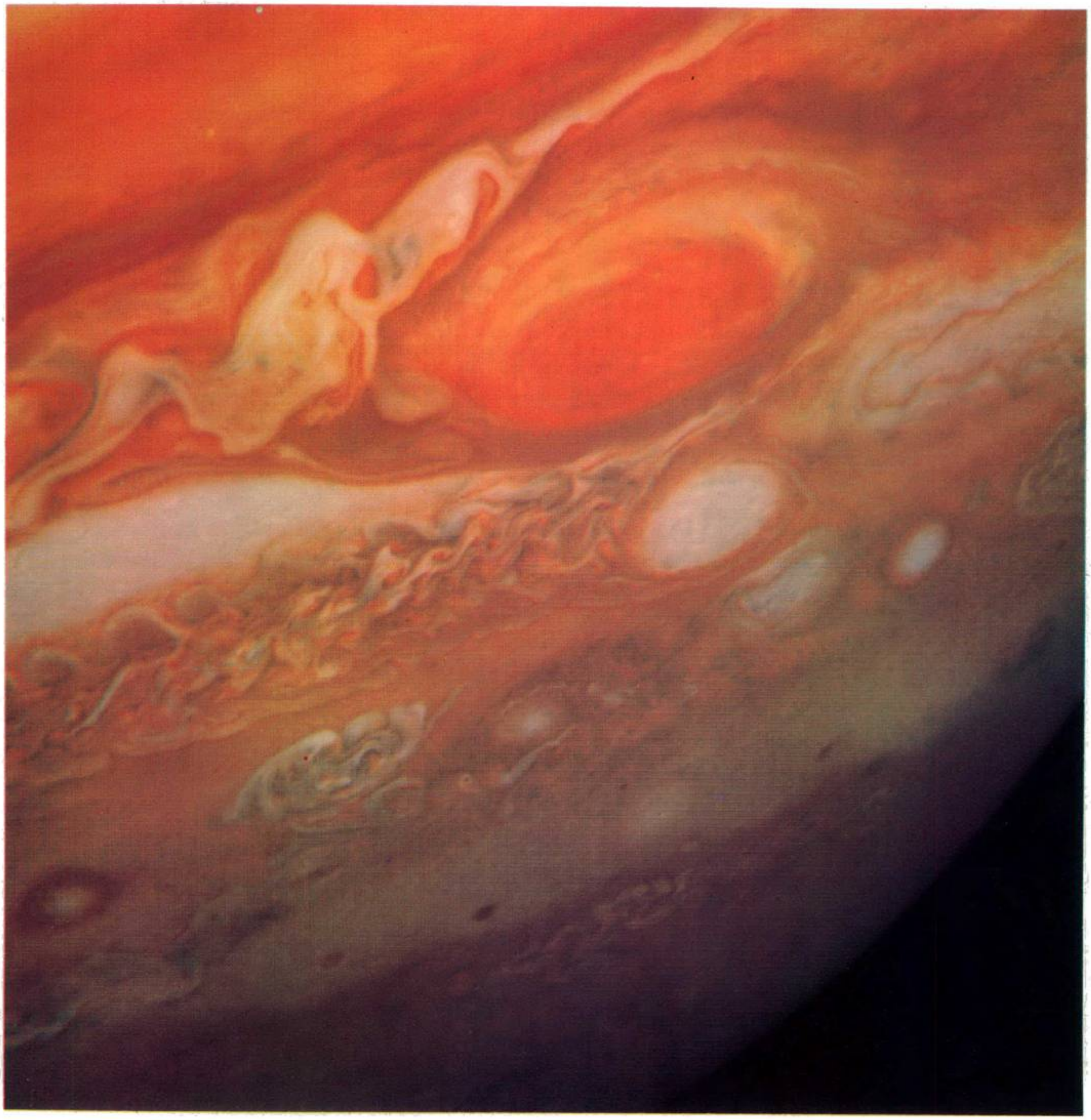

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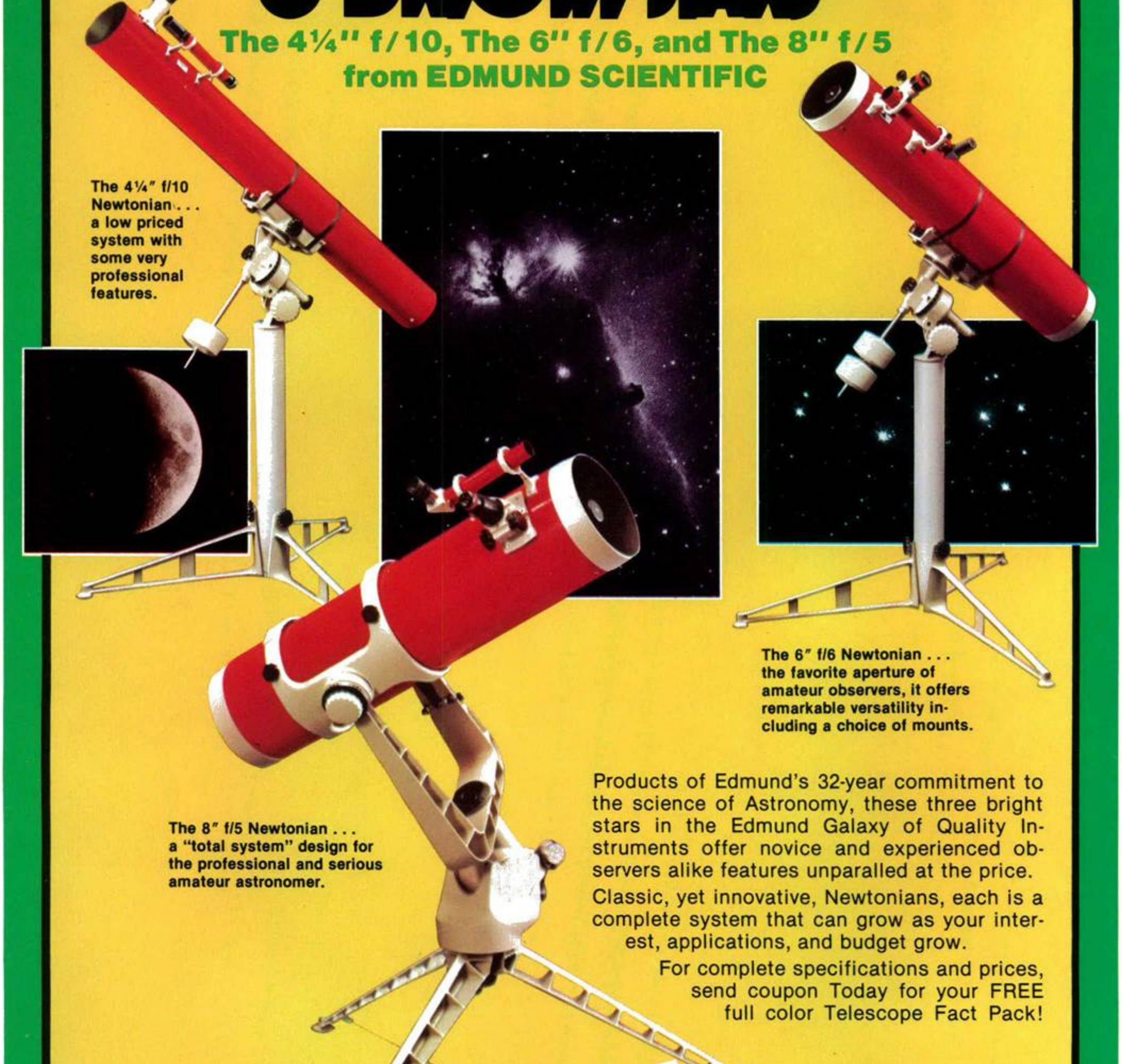

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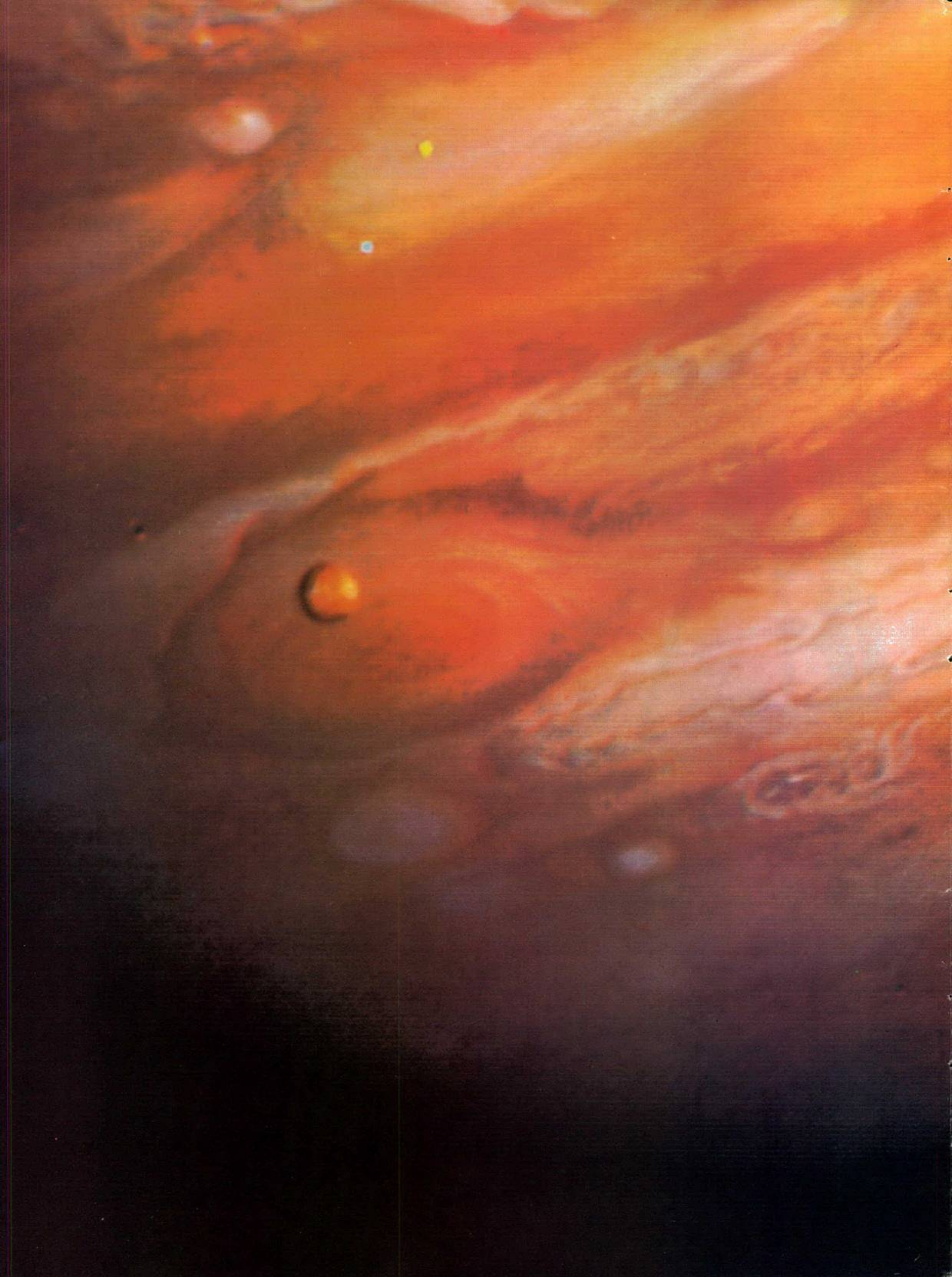

ASTRONOMY

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6 A Voyage to Jupiter

11 Io

14 Europa and Ganymede

18 Callisto

20 The Great Red Spot

In Focus 25

Sky Almanac 26 Uranus Opposes, Meteors Flash

Eclipse Special 34 The Great Midwinter Eclipse

Astro-News 55

Astro-Mart 62

Astronomy Reviews 68

Star Dome 73 Canes Venatici

COVER: This issue of ASTRONOMY is devoted primarily to the pictures from the Voyager 1 Jupiter flyby mission and the first, very exciting, science results. There is no doubt that this mission has already changed the way we think about Jupiter. But perhaps more importantly, the jovian satellites, planets in their own right, have doubled the number of small solar system bodies we've seen in detail. Dewey Schwartzenburg, one of ASTRONOMY's associate editors, covered the mission from the Jet Propulsion Laboratory in Pasadena, California. JPL/NASA photograph.

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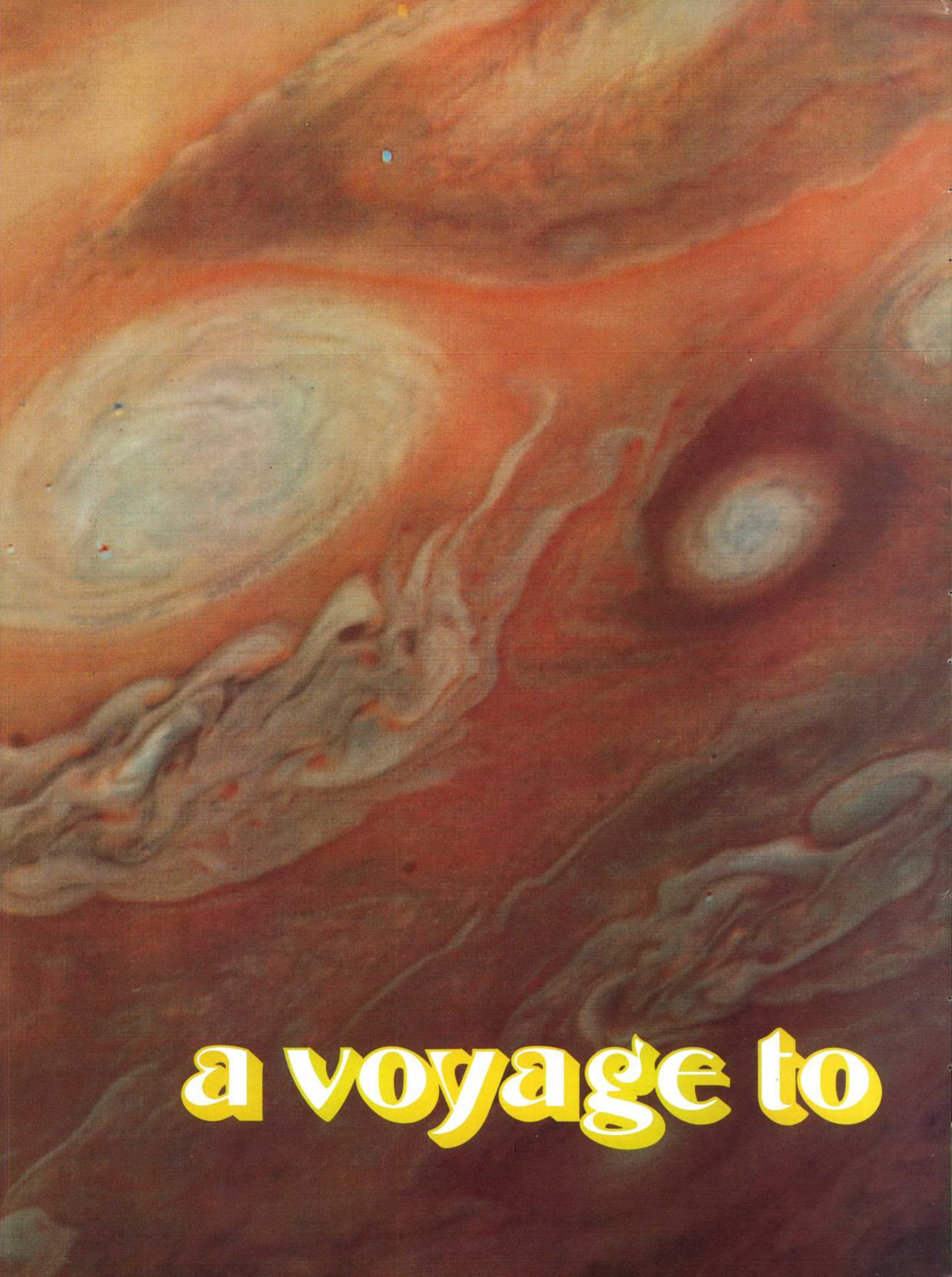

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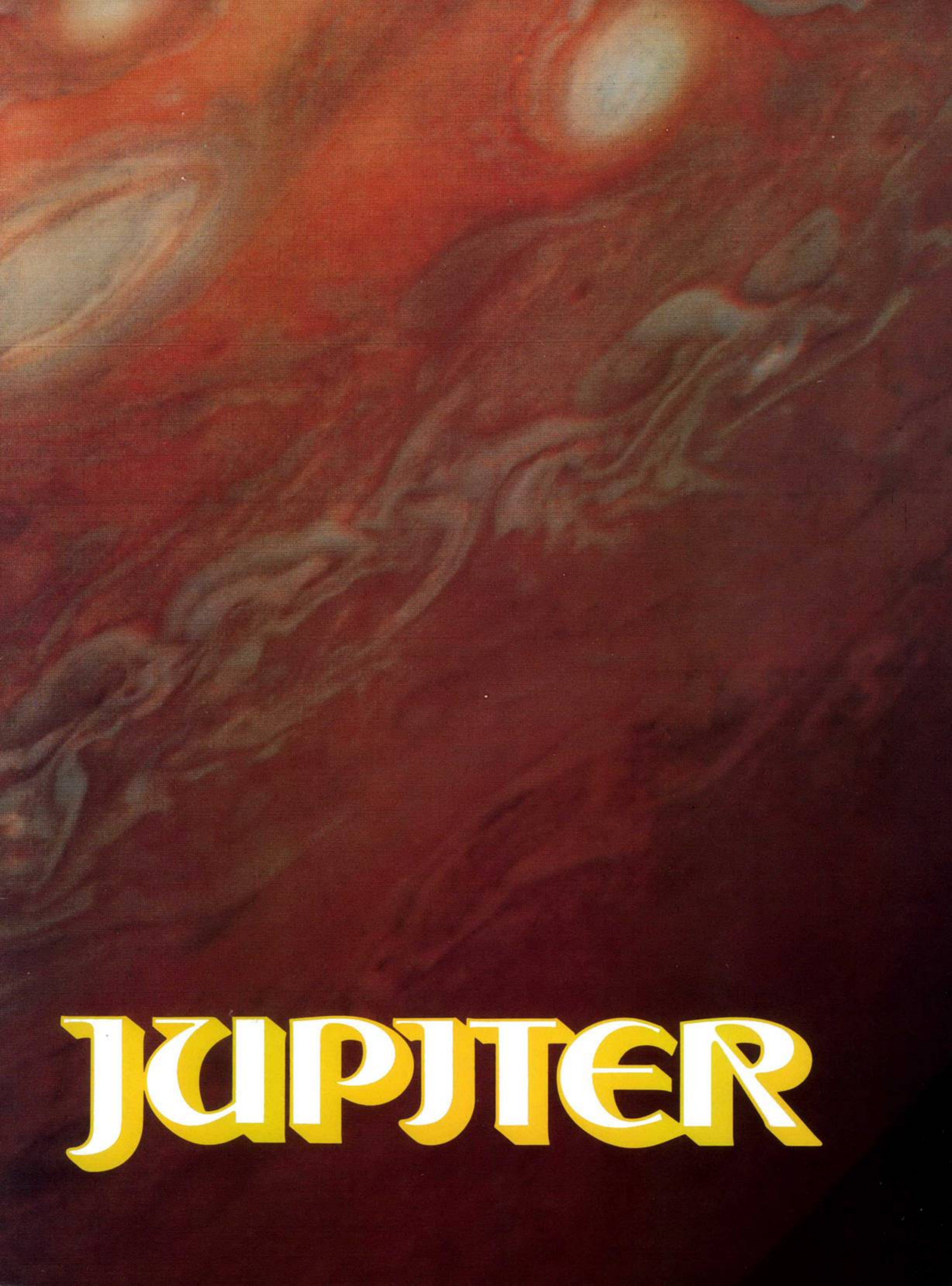
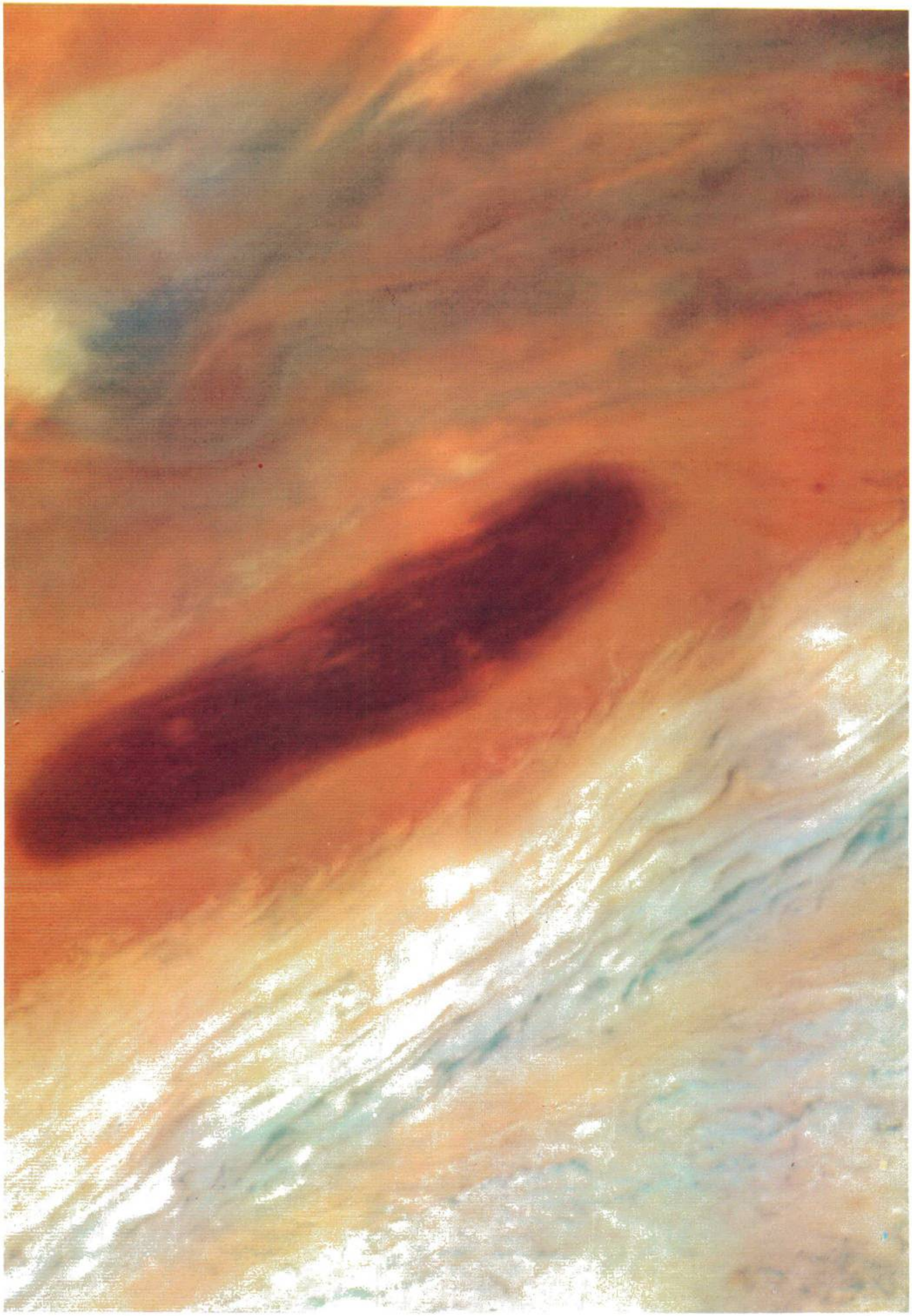


JUPITER



"We knew it would be wild from what we saw on approach, but to anticipate anything like this would have required some sort of heavenly perspective. This is incredible."

Outside it was dark and clear. Among the glittering stars filling the sky above southern California, a single clear, steady light shone high in the west, brightest of all. Here on Earth we call this light Jupiter, and know it to be the greatest of the Sun's children. Barely an order of magnitude short of being a star itself, this giant solar attendant constitutes most of the material in the solar system outside the Sun. It even radiates a bit of its own energy — not much on the scale of the Sun, but twice as much as it receives. The center of a miniature "solar system" of its own, Jupiter commands a family of at least 13 "planets," including four especially large worlds called Io, Europa, Ganymede, and Callisto.

More than five times closer to the Sun than Jupiter, there circles a tiny piece of debris left over from the formation of the solar system — a rocky fragment less than a third of one percent the mass of mighty Jupiter. But that rocky fragment is our home, the planet Earth, and from it a great expedition had been launched. And on the morning of March 5, 1979, as the light of Jupiter shone down on the buildings of the Jet Propulsion Laboratory (JPL) in Pasadena, California, scientists watched the historic encounter images appear on their TV screens. Over 400 million miles from those men and women at JPL, a highly sophisticated robot spaceship called Voyager 1 hurtled past the king of planets at a speed (relative to the Sun) of 81,000 miles per hour. This sophisticated space probe passed 173,000 miles from Jupiter's turbulent surface and went on to make flyby observations of five of Jupiter's moons, taking detailed close-up shots of three of the largest. A worldwide communications network linked the spacecraft with the scientists at JPL, and data never before obtainable poured back in a flood of discoveries.

The Voyager 1 expedition began with its launch from Earth on September 5, 1977 — 18 months before the spacecraft's encounter with Jupiter. Such are the vast distances in the outer solar system that another 20 months of interplanetary travel are required before Saturn, Voyager 1's next target, will be reached on November 12, 1980. The Voyager mission is in fact double, for an identical spacecraft, Voyager 2 (launched 16 days earlier than Voyager 1), is now travelling on a slower trajectory which will bring it to Jupiter on July 9, 1979 — 126 days later than the speedier Voyager 1 — and to Saturn more than 9 months later on August 27, 1981.

The two Voyager spacecraft are not the first probes to explore the realm beyond the asteroid belt. The earlier Pioneer 10 and 11 missions have already passed Jupiter, and Pioneer 11 is even now nearing its encounter with Saturn. But the Voyager probes, both by virtue of their more sophisticated equipment and because of advance information provided by the Pioneer mission, are capable of much more detailed data return. The pictures returned by Voyager are, for example, at least 50 times higher in resolution than those obtained by Pioneer 10 and 11. Whereas the Pioneer mission gave only the most tantalizing glimpse of vague features on Jupiter's moons (showing less detail than the naked eye can see on our own Moon), Voyager 1 returned highly detailed views of those strange worlds.

But study of Jupiter's satellites was only one aspect of Voyager's triple assignment. Jupiter itself, of course, was another: the composition, structure, and dynamics of its unique atmosphere, and, in particular, that strange feature which has puzzled astronomers for centuries, the Great Red Spot. The third area of investigation involved the nature and character of Jupiter's physical environment: its peculiar magnetic field and the vast cloud of charged particles filling it, and the interaction of that rotating magnetic structure with the solar wind and the jovian satellites, especially Io.

It was a great encounter, far more successful than ever hoped for. The quality of the images and data returned exceeded all expectations. Even the first few days brought surprising discoveries: the ring around Jupiter, the complexity of motion and structure in Jupiter's atmosphere, and bizarre surface features on the Galilean satellites. Columbus discovered but a continent; Voyager 1 gave us our first detailed pictures of whole new worlds, three of which are larger than our Moon and two of these even larger than Mercury. Such

JUPITER *continued on page 12*

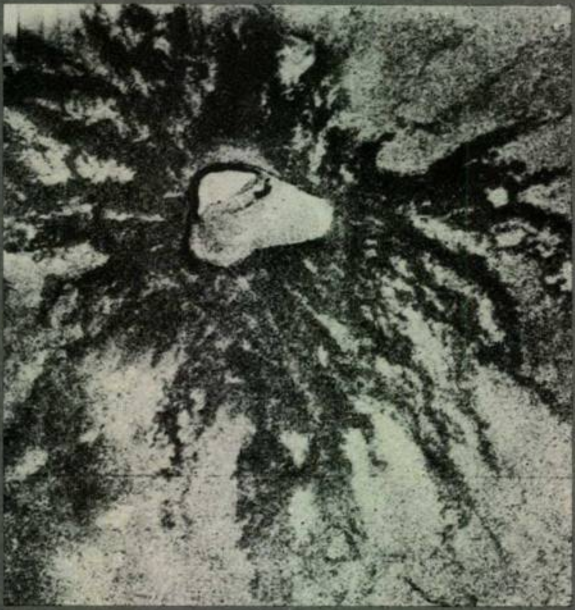
The photograph on the opposite page was taken by Voyager 1 on March 2 at a range of 2½ million miles from Jupiter's surface. The large brown oval, located between 13° and 18° north latitude, may be an opening in the upper cloud deck. Because high resolution observations into such a "hole" could provide information about deeper, warmer cloud layers, the oval was later photographed on March 5, during Voyager's closest approach to Jupiter. Features of this sort, which aren't rare on Jupiter, have a lifetime of 1 to 2 years. Seen also in this image are the pale orange North Temperate Belt and the high-speed North Temperate Current with winds of 260 miles per hour.

Io

"A weird world of bizarre colors, strange features, volcanos, and a young, heavily eroded surface...."

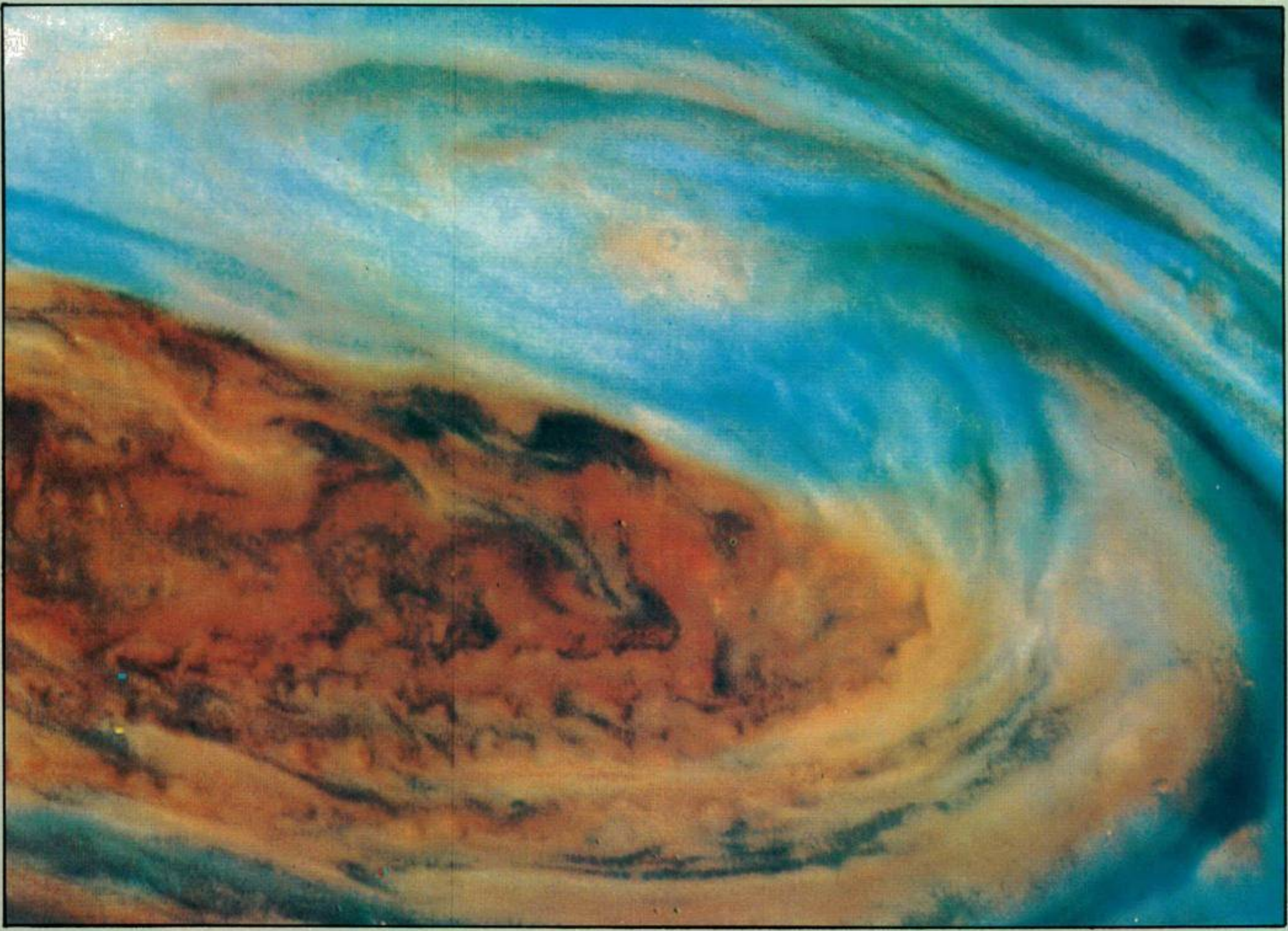
"There ain't no such thing as a boring Galilean satellite," Dr. Laurence Soderblom concluded, and Io is certainly the most surprising and fascinating of the whole lot.

What did we expect? We knew that Io's high density implied that it had lost most of its water, probably leaving behind deposits of various salts on its rocky surface. Yet that surface is highly reflective — with an albedo nine times greater than the Moon's. We expected to find Io an ancient and dead world, heavily covered with craters, perhaps with patches of ice. As Dr. David Morrison said before the Io flyby: "I anticipate — understand this is purely speculation at this point — I would expect when we get the very high resolution pictures here that we would see a surface that looks somewhat lunarlike."



Voyager 1 came closer to Io than any of the other jovian satellites, passing less than 14,000 miles under its south pole. But down to the limit of the highest resolution attained, less than a mile, there were virtually *no* impact features. Scientists scanned the images closely, looking for *anything* that might be a crater, arguing over this formation and that, but nowhere were seen the crowded clusters of craters expected. Instead, Io seems to have a young surface, one no older than 10-100 million years. Obviously some sort of erosion process is taking place. Bizarre color patterns are seen on its surface, and features which look remarkably Earthlike: scarps and channels, rounded hills, and plateaus. Dr. Soderblom commented that Io appears to have cooked and steamed and fumed like Yellowstone National Park. At least one volcano was found, so it seems that Io is still internally active.

Could the peculiarities of Io be explained by the high-energy, charged plasma environment through which it moves? We don't yet know. But we do know that it has no atmosphere which could help account for erosion. The presence of vulcanism indicates that something is keeping the interior of Io stirred up and active, and something is keeping the surface pliant and young. At present, scientists believe Io's unique high energy environment — orbiting inside a plasma torus, attached to Jupiter by the umbilical cord of the electromagnetic flux tube, and constantly bombarded by high energy particles — may provide a mechanism which has never been seen anywhere else and which may account for the constant erosion and modification of Io's surface — *the strangest we have yet seen in* the solar system.



The views of Jupiter on these two pages have greatly exaggerated color. The colors represent not the true hues seen in the jovian atmosphere, but enhanced color. They were produced by special computer processing to exaggerate the subtle variations in both color and contrast. The Great Red Spot, shown above, is overlain with what may be a layer of (blue) clouds spreading across its northern part. At right is a complex region of turbulence just to the southeast of the Great Red Spot. Its upper right corner overlaps the lower left corner of the first picture, the two views forming two parts of a mosaic of this intriguing region.

JUPITER *continued from page 9*

mountains of information were returned by Voyager 1 that it will be years before it is all analyzed.

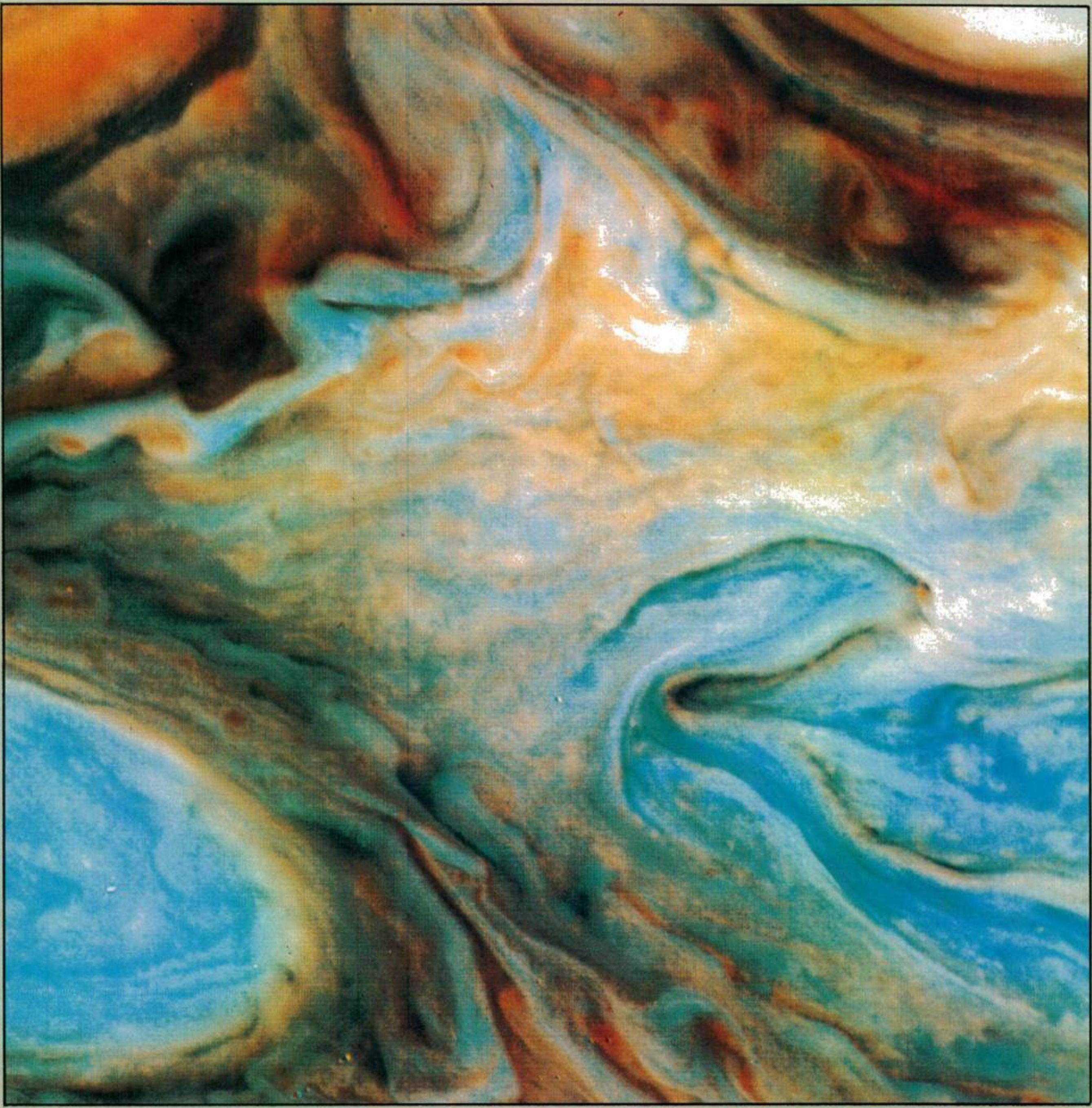
But even the early results were clearly phenomenal, both in quantity and quality. "We obviously had expected certain things," said Dr. Edward Stone of CalTech, chief Project Scientist on the Voyager 1 mission, "but what we found when we went and made a measurement is that not only is it different, which is interesting, but in fact it's different in a way that's telling us something we hadn't understood before."

The excitement of discovery was enormous — Dr. Brad Smith of the University of Arizona, leader of the Imaging Science team, frankly admitted that during the near encounter itself, project scientists, forgetting their work, stood open-mouthed around imaging screens as scenes from 400 million miles away slowly appeared line by line. At one point, Dr. David Morrison, jovian satellite specialist, leaned close to the viewing screen as a close-up of a peculiar, as-yet-unnamed feature on Io appeared for the first time and murmured, "Fantastic! That's just fantastic!" Unoriginal words perhaps, but they and others like them were heard all over JPL that night: "Fantastic!" — "Unbelievable!" — "Great!" — "Just look at that!" — and just plain "Wow!"

What was it like to make this journey of exploration and discovery? Let us join the Voyager 1 spacecraft shortly after launch, and travel along with it to Jupiter — modern explorers on a mission which is still only half over.

This journey we take may ultimately remove us 30 times as far from the Sun as man has yet ventured — and it could last as long as eight years. Our mission is marked by a variety of phases as we approach the two primary goals: Jupiter and Saturn.

The first phase, known as *early cruise*, lasts for the first three months, while a crescent Earth and its Moon recede behind us. During this phase, our trajectory is adjusted to provide the optimum approach to Jupiter. It's a time of housekeeping — checking out spacecraft systems and instruments, performing calibrations and tests. Our ship is stabilized by automatic sensors trained on the Sun and the star Canopus, but it seems that slightly too



much fuel is being expended to maintain our attitude. The fuel supply must last for years, so to conserve it, the sensitivity of the Sun-sensors is reduced slightly so that the automatic control system won't be so quick to fire the attitude control jets. We had planned to take advantage of an opportunity to study comet Kohler, a newly discovered comet rushing into the solar system, but careful calculations show that to do so we would have to point our delicate instruments too close to the Sun. Still quite close to that blazing heart of the solar system, we dare not risk damage to the optics of the imaging cameras by pointing them toward the Sun for any length of time.

However, another opportunity for scientific work presents itself. During this phase of our journey, a unique alignment occurs. Helios, a spacecraft in solar orbit between the Sun and Earth, happens to pass directly between Earth and the Sun. And Voyager 1, farther out in the solar system, happens to be lined up with these three bodies. As the solar wind streams out from the Sun, it first passes Helios before encountering Earth with its deflecting magnetic field. It then spreads out to meet Voyager 1. Important data is obtained on the interaction between planets and the solar wind. The early cruise phase of the expedition concludes with pointing the spacecraft's high-gain antenna toward Earth. Without this, communications over the now-great distance separating us from home would soon become impossible.

JUPITER *continued on page 16*

EUROPA

"A bright, somewhat featureless world, covered perhaps by a planet-sized glacier scarred with huge cracks...."

Voyager 1 didn't pass very near to Europa, coming no closer that 455,000 miles. Detailed examination of the second Galilean planet is scheduled for July 9, when Voyager 2 swoops to within 125,000 miles of its surface, providing four times better resolution of its features.

The best pictures obtained of Europa, though, show it to be very different from the other large jovian satellites. We see no sign of any large impact features, which is somewhat surprising. Is Europa, like Io, relatively free of craters, another "young" planet in the jovian system? What we see are huge cracks across one hemisphere, cracks as much as a hundred miles wide, stretching for thousands of miles across Europa's face. They look like nothing so much as splits in a solid ice crust. Like Io, Europa has a high density, implying that it is chiefly composed of heavy, rocky materials; but also like Io, it has a high albedo, efficiently reflecting most of the light falling on its surface. Maybe Europa is covered by a planet-size glacier a mile or more thick, but there is no need to speculate: we will only have to wait a few months to find out.

GANYMEDE

"A torn and tortured globe, sheared and faulted again and again, covered with craters and strange bright patches...."

Ganymede is larger than Mercury, but has a density almost three times less. We know this third jovian planet must be composed mainly of ice all the way through, but up close, we have now discovered a surface amazingly torn and twisted. Voyager 1 passed within 72,000 miles of Ganymede's tortured surface, and Voyager 2 will provide a look from half that distance. But already the close-up views from Voyager 1 show an involuted pattern of lines and ridges, looking like plowed fields in some places, in others like snowmobile or dune buggy tracks. The scale of these features, however, is much larger than these terrestrial analogies: the "tracks" are miles across, and hundreds of miles in length. They probably came about from deformations in Ganymede's icy crust. The bright streaks of the ray splash patterns form an overlying tracery.

We know that Ganymede — like Callisto, but unlike Io and Europa — has a not very reflective surface despite its low, ice-like density. The surface, therefore, is likely a mixture of dirty ice and rocks, while the bright features could be deep, underlying, "clean" ice thrown up and out by meteor impacts. Likewise, the grooved sections, lighter than the surrounding terrain, probably expose cleaner ice just below the surface.

A number of impact craters are seen, as expected, but there is a peculiar distribution in size: there aren't many big craters. Huge fault lines can be seen, along which sections have shifted 30 to 50 miles or more. The scientists agree that "plate tectonics" is not the right phrase, but sections are obviously faulted, sheared, torn apart and slid around. We are seeing surface physics and geology never before seen anywhere in the solar system. Every one of the jovian planets has turned out to be unique.

JUPITER *continued from page 13*

We now enter the long *cruise* phase of the mission, which lasts for nearly a full year. After crossing the orbit of Mars during the early cruise, Voyager begins the long trek across the Asteroid Belt. There is no real danger, we know, because the distances between even the tiniest asteroids are so great that the chance of encountering one is infinitesimal. Even so, knowing that thousands upon thousands of minor planets orbit out here, we never quite relax completely.

Cruise phase is a quiet time, occupied with routine tests and continuing calibrations. The instruments are working fine, except for a nagging problem in the filter wheel of the imaging camera. It looks like the engineers will solve it in plenty of time for the Jupiter encounter, though. A limited number of stellar targets are examined, and early in the cruise phase, we successfully perform a fairly detailed mapping of the Great Nebula in Orion.

On February 23, 1978, a real problem develops. The scan platform, which supports and aims the cameras and several other important instruments, becomes stuck. Weeks of frantic analysis and work follow — if we can't fix the scan platform, we may very well be blind when we arrive at Jupiter. On the hunch that a small piece of plastic got jammed in the gears, mission engineers send the appropriate signals, maneuvering the platform until it crushes the debris. Another problem is solved.

As time passes slowly and quietly, the immense distance still to be covered grows less and less. The long calm is shattered, at last, during the final three days of the cruise phase. Still months from encounter, Voyager successfully executes a full dress rehearsal of the frantic activities scheduled for the short period of our closest approach to Jupiter. The simulation does seem a bit ludicrous, however, as the scan platform zips from place to place imaging a phantom planet and its phantom moons.

Now it's time to begin making detailed plans for our observations during the quick flyby. The scientists want to be fully prepared. After all, we'll have only a few hours to observe Jupiter closely, and must decide exactly what part of the planet to zero in on with our instruments. It's not enough simply to determine which features look most interesting right now. Planetary meteorologists must engage in some tricky, long-range jovian weather forecasting. Everything we see on Jupiter is weather; we must decide *now*, months before encounter, what are likely to be the most active and interesting regions to look at when we arrive. The scientists, working through control computers, command Voyager to shoot a twenty-hour sequence — two full rotations of Jupiter — for careful examination. By now, at the end of the cruise phase in December 1978, Jupiter shows more detail to our cameras than the very best groundbased telescope photographs.

Sixty days and less than 38 million miles out from Jupiter, the *observatory* phase of the mission begins. Intensive observations continuing for the next 26 days will provide an overview of significant phenomena on Jupiter. Daily "system scans" by the instruments take a large-scale look at the entire Jovian system. Atmospheric processes on Jupiter are watched closely to look for the most dynamic features, as the meteorologists prepare for the brief flyby. It is already obvious that the Jupiter of the Voyager 1 mission is very different from the Jupiter of the Pioneer 10 and 11 missions. The excitement begins to mount as the giant planet draws visibly closer every day, its disk showing more and more detail.

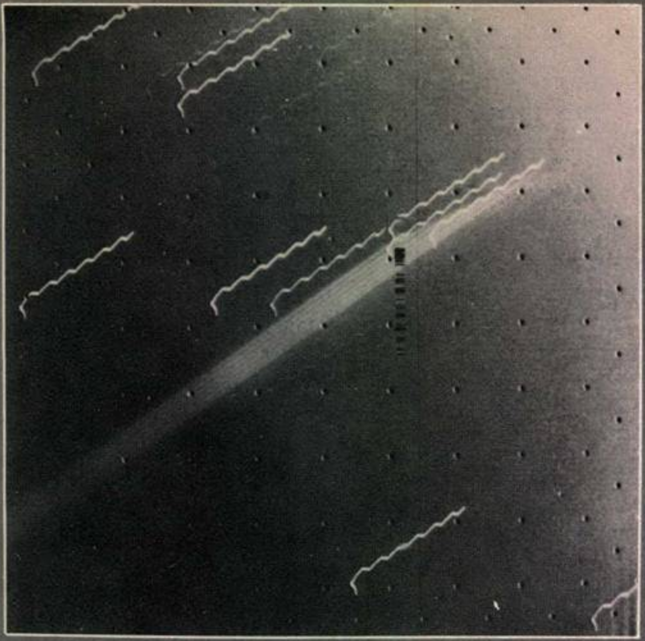
As the observatory phase draws to a close, Voyager performs the first of its final trajectory correction maneuvers to put it exactly on target for flyby — March 5, 1979. At the end of January, we begin a four-day period of intensive picture taking, shuttering the cameras every 96 seconds for 100 hours. Ten full jovian rotations are radioed back to Earth in what is essentially a "movie" of Jupiter's rapidly changing atmosphere. The surface of the planet may be all "weather," but what weather it is! Storms larger than our entire planet swirl across its surface while jet streams thousands of miles across race around the globe. Twisting eddies as big as terrestrial continents bubble and boil between the rushing belts of clouds. The movie shows the gigantic Red Spot, large enough to swallow up several Earths, spinning like a hurricane.

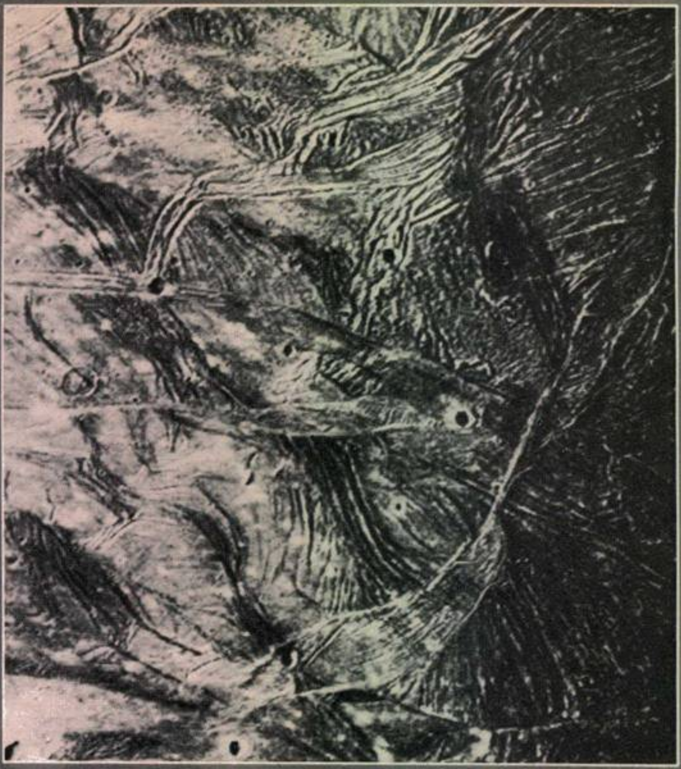
On February 3, 1979, Voyager 1 begins its *far encounter* phase, eighteen and a half million miles from Jupiter. One last course correction for Jupiter is made as observation of the four largest satellites, Io, Europa, Ganymede, and Callisto, begins. With the crossing of the orbit of Jupiter's outermost known satellite on February 10, we officially enter the jovian system. Tiny Sinope, more than 15 million miles from her master, is only about 9 miles in diameter, and is not observed.

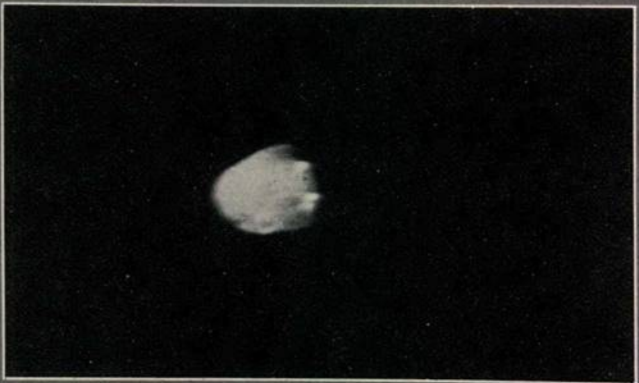
Far encounter phase continues until March 4, one day before closest approach. *Near encounter* phase will be a 39-hour period packed with close-range measurements by the 11 science experiments aboard.

As the time of near encounter approaches, Jupiter begins to reveal more and more wonders. The wealth of detail and structure visible in the cloud system amazes us. Meanwhile, scientists ponder the difficulty of the task before them: designing models of atmospheric structure and dynamics to account for such complexity. Some processes are clearly evident: convection, instability, and wave generation. And some regions show recognizable upwellings of cloud particles, and therefore, the invisible gas carrying the clouds is rising from below to spread out over the

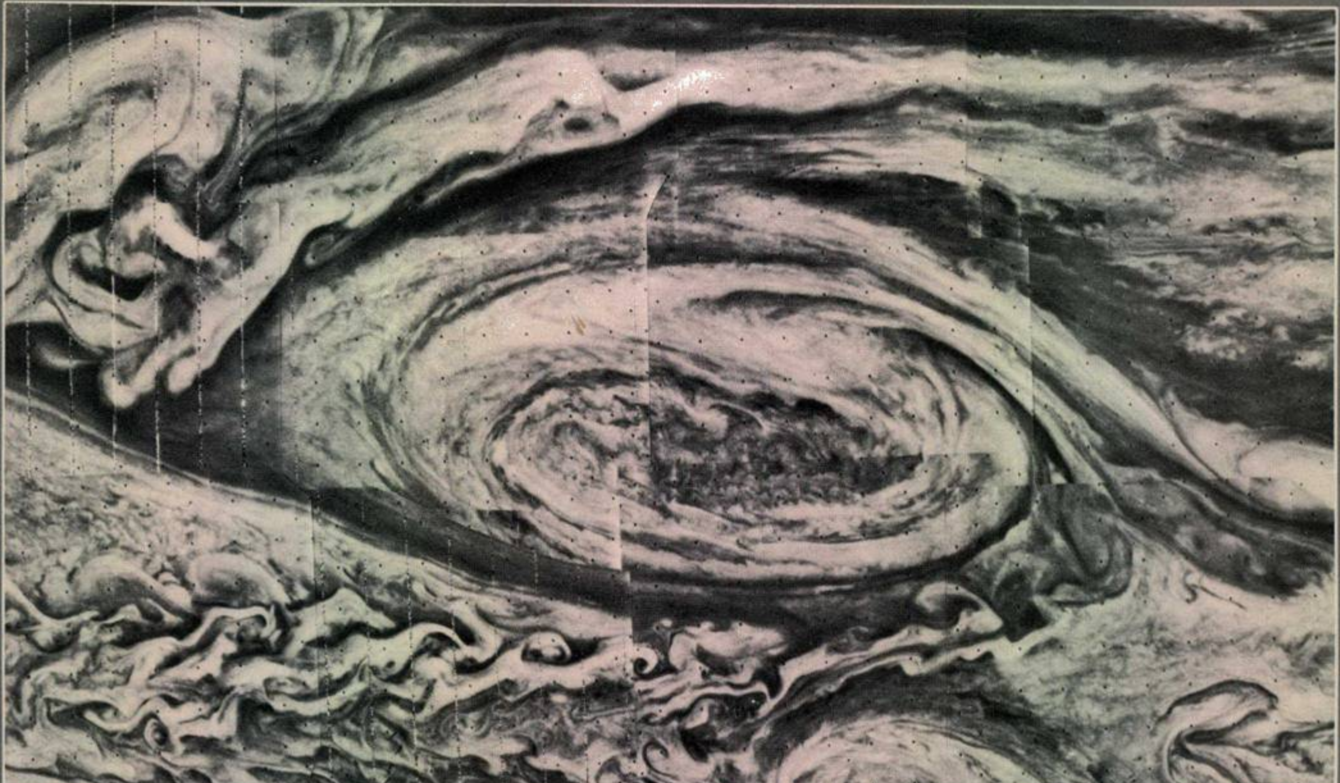
JUPITER *continued on page 23*







Upper left: The discovery photograph of Jupiter's ring, taken by Voyager 1 on March 4, 1979. Six separate images of the exceedingly thin ring are seen because of the spacecraft's motion. The other streaks are trails of stars in the Beehive Cluster (M-44). Above: A close-up view of the torn and twisted surface of Ganymede, Jupiter's largest "planet." The picture covers an area about the size of the state of Indiana. Left: Tiny, red Amalthea, Jupiter's innermost satellite, is an elongated chunk of rock about 80 by 140 miles. Below: This mosaic of the Great Red Spot reveals much of its complex structure never before seen. Note the fine granulation of the clouds in the center of the Spot.



CALLISTO

"Craters shoulder to shoulder all over this Galilean world, and the largest feature ever seen in the solar system...."

Another surprise — in a system filled with them. Callisto, outermost of the four Galilean satellites and about the size of Mercury, has, like Ganymede, a low density. From this we deduce that, also like Ganymede, it must be composed chiefly of water-ice mixed with rocky materials. Scientists expected to find very few craters here, maybe no surface markings at all, just a frozen ice world. Instead, we found the largest permanent surface feature in the known solar system. And we see a world densely covered with craters — an extraordinarily high density of craters — but with a peculiar size distribution: there are very few large craters.

Callisto is the darkest of the jovian worlds, only half as reflective as Ganymede but still twice as bright as the Moon. This suggests that like Ganymede, its upper surface is "dirty ice" or frozen, water-rich rock.

Flying above the north pole of Callisto on March 6, at a range of about 77,000 miles, Voyager 1 photographed a surface closely packed with small craters in the 12 to 30 mile diameter range. Callisto has far more craters than even Ganymede, leading scientists to believe that its surface is the oldest so far observed in the jovian system, possibly dating back to the final accretional stages of planet formation 4 to 4½ billion years ago. Callisto also seems to have a thicker crust than Ganymede.

The most prominent feature seen was very prominent indeed. A huge bull's-eye type formation stretches across 1600 miles of Callisto's landscape. A light-floored central basin, about 200 miles in diameter, is surrounded by at least 8 to 10 concentric, evenly-spaced mountainous rings. No evidence of rayed ejected material can be seen, but the feature is clearly caused by impact of a large object. This object may have broken through Callisto's crust entirely and been swallowed up in its interior as the force of the impact sent waves rippling out through the icy crust, waves which quickly froze into place as we see them now. Such a feature is unique in the solar system, but by now we have learned not to be surprised by anything in the endlessly varied and diverse jovian system.

the Great

Red Spot

JUPITER *continued from page 16*

background of other features. Looking into the central part of the Great Red Spot, we see a tiny granulation. This is suggestive of convection, but what's happening in the core of the Red Spot isn't immediately obvious. This core doesn't rotate, but the outer regions of the Red Spot do display a counter-clockwise spiral motion. Scientists measure the scale of the granulation and find it to be hundreds of kilometers in size. Some cloud layers seem to be overlying other, deeper ones. And "hot spots" — areas distinctly warmer than surrounding regions — appear to be "holes" in the clouds through which deeper and hotter layers can be seen.

Jupiter's atmosphere is composed primarily of hydrogen and helium — with other gases as minor constituents. They are all clearly detected: molecular hydrogen, ammonia, methane, acetylene, ethane, deuterated methane, and water vapor; even difficult-to-detect helium is indirectly confirmed. The temperatures of the thin, upper atmospheric layers are fairly uniform over the entire planet, though it's slightly warmer in the north and colder in the south. Even though its axial tilt is small (3°), Jupiter clearly shows the effect of seasons. With atmospheric dynamics more complex, detailed, and turbulent than had been believed possible, the old question reasserts itself with greater force: why do features such as the Great Red Spot and the white spots of the southern hemisphere endure so long?

As the spacecraft races in ever faster and closer, our scientific instruments are also studying the strange environment of Jupiter. The intense magnetic field of the giant planet rotates along with it: magnetic field lines sweep around and through the jovian system. A thin plasma gas of ionized atoms and electrons filling the region interacts with the magnetic field, stretching out into a flat spiral disk of magnetized plasma sweeping out from Jupiter.

Where the solar wind blows against this huge magnetic system, a bow shock wave is set up, diverting the solar wind around the magnetosphere. Our spacecraft is due to cross this bow shock a few days before closest encounter, but in fact, we find that we cross it several times in succession. The pressure of the solar wind, varying in its intensity, causes the bow shock to bounce in and out like a spring, moving alternately closer and farther from Jupiter. So the bow shock sweeps back and forth along our trajectory, and the spacecraft repeatedly moves in and out of the jovian magnetic region. The boundary of this region obviously varies a great deal, for we observe it on this particular journey at distances as far out as 86 jovian radii (over 3,800,000 miles) and as close as 47 jovian radii (less than 2,100,000 miles).

For each picture shown on these pages, this table gives the date taken and the distance between the Voyager 1 spacecraft and the object. The picture number is NASA's designation and specifies the image uniquely in their files.

Page	Date	Range (miles)	Picture #
Cover	Feb. 25	5,700,000	P-21151C
4-5	Feb. 13	12,400,000	P-21082
6-7	Mar. 1	2,700,000	P-21183C
8	Mar. 2	2,500,000	P-21194C
10 top	Mar. 5	18,480	P-21281
10 bottom	Mar. 5	50,000	P-21221
11	Mar. 4	500,000	P-21209C
12	Mar. 4	1,100,000	P-21229C
13	Mar. 4	1,100,000	P-21225C
14 top	Mar. 4	1,200,000	P-21208C
14 bottom	Mar. 4	1,600,000	P-21207C
17 top, left	Mar. 4	1,212,000	P-21258
17 top, right	Mar. 5	87,000	P-21279
17 left	Mar. 4	225,000	P-21223
17 bottom	Mar. 1	1,100,000	P-21203
18	Feb. 28	5,000,000	P-21188
19	Mar. 6	217,000	P-21287C
20-21	Mar. 1	3,000,000	P-21182C
22	Mar. 5	226,000	P-21226C

Dewey Schwartzenburg, of ASTRONOMY's staff, covered this exciting event during the seven frantic days of the Jupiter encounter in the pressroom at JPL. JPL manages and controls the Voyager Project for NASA's Office of Space Science; all photographs in this article courtesy of JPL and NASA.

Once into the magnetosphere of Jupiter itself, we find space filled with charged plasmas and highly energetic particles. In addition to the expected protons, other energetic nuclei are found: oxygen, carbon, nitrogen, magnesium, sulfur, neon, silicon, and iron. The abundances of the high energy nuclei are similar to those in the solar wind, but the low energy nuclei include an extraordinarily high proportion of sulfur nuclei. Where does this sulfur come from? We suspect Io. A large-scale electrical current flows along the boundary of the magnetosphere and a ring of current flows in its equatorial plane (which is slightly inclined to that of Jupiter). These currents vary significantly as time passes.

The inner magnetosphere, as we expected, is very "stiff" and rotates rigidly along with Jupiter itself. Like a magnetic disk firmly attached to the planet, it drags the charged plasma particles along. They spin around the planet like billions of tiny

JUPITER *continued on page 48*

Voyager 1 took this picture of Io, the innermost Galilean satellite, on the morning of March 5 at a range of 226,000 miles. Because of the processing method, the reddish color is exaggerated. Io is actually more orange than red, as in the photo on page 11. It isn't yet clear whether or not the strange heart-shaped feature seen in the center is a topographic structure seen in relief or a pattern of low-relief surface markings. The reddish, white, and black areas are probably surface deposits, perhaps mixtures of salts, sulfur, and lava. Many of the black spots are associated with craters of possible volcanic origin. Scientists have agreed that since the Greek and Roman myths have now been virtually exhausted, the newly discovered surface features on each of the jovian satellites will be named for persons, places, and things in the mythologies of other cultures.

Jupiter Fly-By!

Voyager 1
March 5, 1979

The finest NASA images from the historic mission are now available in a high quality full-color poster on heavy stock. Featured are stunning photos of Jupiter, The Red Spot and the "new Planetary system", the four Galilean satellites. Designed to be framed intact or divided into individual images, this up-to-the-minute poster captures all that's new and exciting about our giant neighbor.

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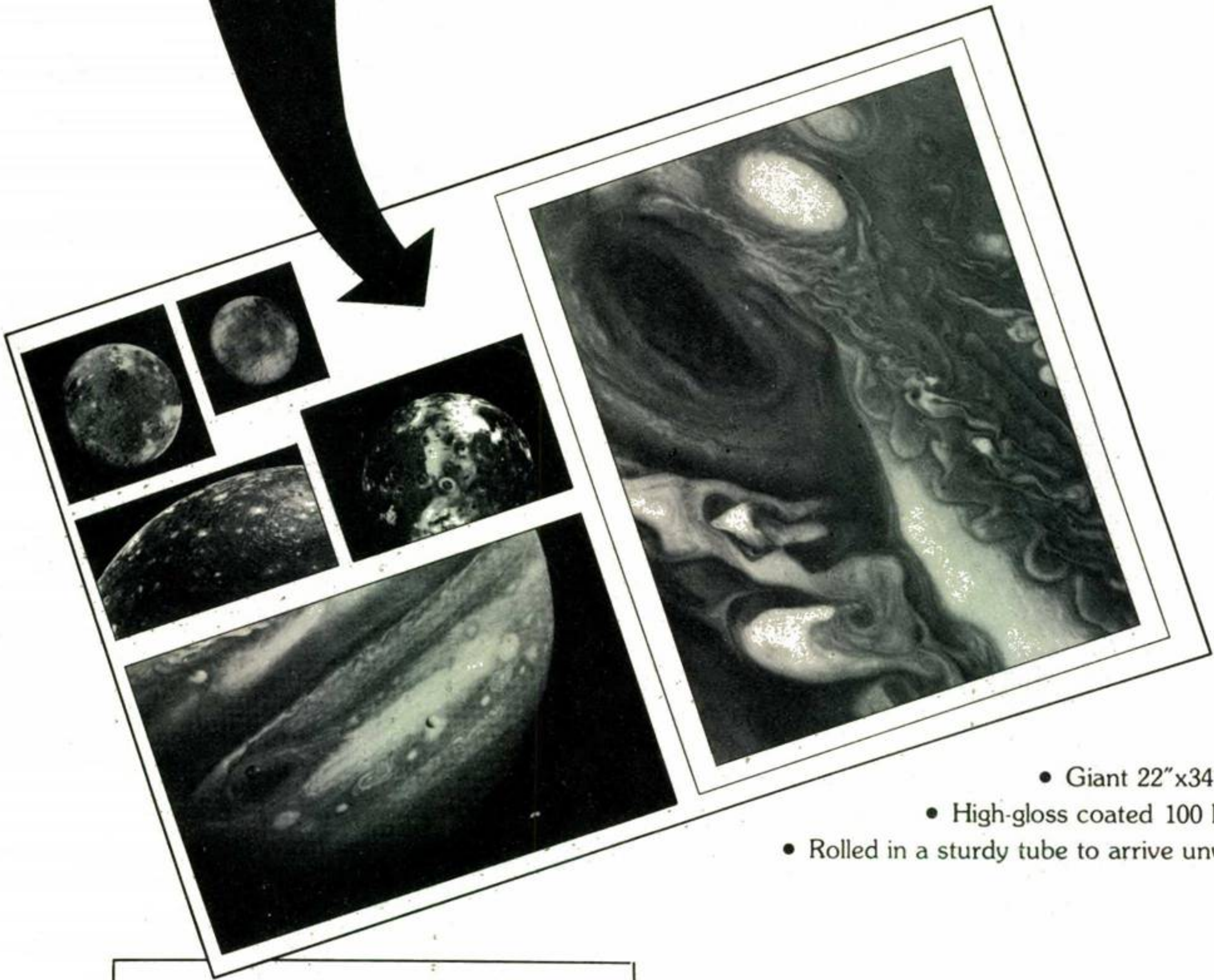

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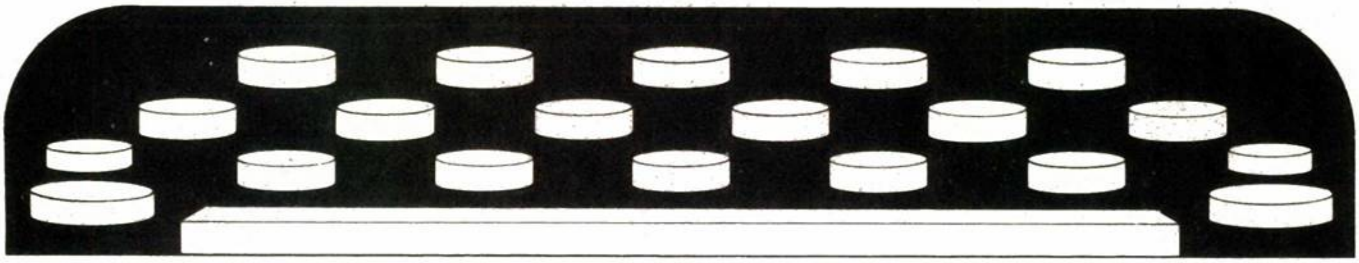


IN FOCUS

Sir / Whatever the monks saw in 1178, it wasn't a "new" lunar crater; the time scale is wrong. (See January issue, page 18.) The monks' description is much too fast for crater formation effects. Assuming that ejecta from the crater travel at 2 km per second, the eye won't notice any changes for at least a minute, and then the changes will take 15 to 20 minutes to rise and fall back, forming the rays. The appearance will not be "sudden," and the movement will seem more analogous to a plodding turtle than a "writhing snake."

The monks' description does match what happens when the Moon passes through an inversion layer. The conditions for this rare phenomenon were present. It was a late spring evening, when the Moon was close to the horizon. Turbulent air can refract moonlight by several minutes of arc. Did the Moon set over someone's hot chimney?

WALKER S. VANING
Dallas, TX

Mr. Vaning / While it is true that the development of a 20-km-diameter crater will require several minutes, and tens of minutes will pass before much of the ejecta falls back to the surface of the Moon, I believe use of the term "suddenly" to describe the onset of the phenomenon is entirely consistent with a lunar impact causing the phenomenon. The early ejecta from such an impact, although representing only a small portion of the total mass of ejecta, may move away from the impact site at several times the impact velocity, or up to several tens of kilometers per second. This material also will be heated to the highest temperatures, will be incandescent and, therefore, more easily seen from Earth. Thus, certain aspects of the phenomenon, in particular the ejecta shadow and the fire and hot coals, could become visible within about 10 seconds of the impact.

The "writhing snake" phenomenon is not easily explained by any model. It seems reasonable to attribute this to viewing the Moon through volumes of gaseous material having varying indices of refraction. The question is whether the gas was part of a temporary lunar atmosphere produced by the impact or part of Earth's atmosphere. In either case, the period of the "writhing" cycle would be expected to be more like a minute than a few seconds. In this case, I think we must allow some latitude in the time scale for the comparison with a "writhing snake." It may be that the "writhing" was a terrestrial atmospheric effect, but much of the description is not readily explained by viewing the Moon through an inversion layer. Inversion layers and setting crescent moons are both common phenomena, and available observers are abundant, but no description similar to that recorded by Gervase of Canterbury has ever been made, to my knowledge.

Taken alone, the "writhing-snake" moon may be ignored. Even the entire account, by itself, need not be taken too seriously. But the recorded account and the existence of an obviously recently-formed crater at the right place seem beyond coincidence.

DR. JACK B. HARTUNG
SUNY, Stone Brook, NY

Sir / Late in 1978, the U.S. Department of Health, Education, and Welfare revealed a $7 billion loss due to welfare fraud and inefficiency. Not mentioned, of course, is the fact that this is close to *twice* the size of the NASA budget. So much for those critics who contend that space money would be better spent on HEW-type projects. (If NASA had received that $7 billion instead of the cheats, you can bet that we wouldn't be losing Skylab today.)

However, to the point. This HEW admission is a reminder that 1) for too long, NASA has allowed itself to be pitted against government welfare programs when it comes to financing, and 2) that the general public (and the media) are only too inclined to gross overestimates of NASA spending levels.

Why don't space advocates use comparisons that put our national space investment in terms the man on the street can comprehend? Why not use figures that de-emphasize the welfare shibboleth — that reveal, instead, how puny our space commitment really is.

As just one example: how many people are aware that in 1978, the McDonald's hamburger people will show sales equal to or better than the NASA budget? (I slipped this fact into a food industry reference book just published, and already it has caught the eye of a Washington journalist.)

Here are some other comparisons your readers might try on more dubious friends, co-workers, students, media persons, or, for that matter, politicians:

Compared to the NASA budget...

- American spending in discotheques is about equal.
- The estimated cost to business of filling out federal forms is 4½ times larger.
- Two states — New York and California — each paid out more in public welfare in 1975 (not including health or eduction).
- A&P store sales are nearly double; Sears Roebuck sales and Boeing sales are slightly bigger. And, IBM profits are currently running at about ¾ of the NASA budget.

Still other comparisons:

- Americans spend 1½ times as much on pizza (fresh and frozen) as they do on the civilian space effort. The same is true for toys, while cosmetics sales are *three* times as big.
- The 1979 capital outlay to meet government safety and fuel standards by General Motors alone will be about equal to the NASA budget.
- Legalized casino gambling in Nevada and Atlantic City grossed $1.9 billion last year — nearly half as much as NASA's entire appropriation.
- Just one of many, many welfare programs — unemployment benefits — in 1976 ran four times larger than NASA.
- For that matter, American teenagers could finance seven space programs each year if current estimates of their discretionary spending power are accurate.
- What if Americans were to give up just one of their major vices and give the $$ to Gerald O'Neill instead? He'd have all the financing he needs to get cracking on his L-5 project, with pocket money left over. I'm talking about the estimated $25 to $40 billion for marijuana — the $20 billion for cocaine — the $17 billion for tobacco spent each year in this country.

It would seem to me that our national priorities are really out of line. Who says we can't afford space?

JULIE WOODMAN
Chicago, IL

SKY ALMANAC

Uranus Opposes, Meteors Flash

The "merrie monthe of Maie" offers a number of attractions, not the least of which are several pre-dawn conjunctions. In addition, Saturn's rings become as visible as they ever will this year, Uranus comes to opposition, and there's a chance for you to help pin down the date of a meteor shower's maximum. All this and the return of warmer weather will lure you outside to resume your observing (or were you one of the hardy types who never gave up all winter long?).

Mercury

Sad to say, May offers poor prospects for Mercury followers. Apart from a conjunction with Mars on the morning of the 5th, when Mercury will be about 2° to the south of Mars, the little planet will be hard to see.

Upcoming Events — June

2	First Quarter Moon
10	Full Moon Neptune at opposition
12	Jupiter passes M-44 (Beehive cluster)
17	Last Quarter Moon
21	Solstice
22	Occultation of Aldebaran
24	New Moon
26	Moon 5° south of Mercury
27	Moon 3° south of Jupiter
30	Moon 2° south of Saturn

Continuing the recent spate of conjunctions, June has three during the last week of the month, though they happen in the evening sky instead of the morning.

The occultation of Aldebaran will be visible over almost all of the U.S. and Canada, except the Florida peninsula, the southernmost tip of Texas, and Alaska.

At the time of conjunction, Mercury will be at magnitude +0.1, Mars at magnitude +1.4. Both planets' apparent sizes will be small: Mercury, 6.3 seconds of arc; Mars, 4.1 seconds. Venus at magnitude -3.3 will gleam to the upper right.

By the 29th, Mercury will be at superior conjunction and lost in the Sun's glare.

Venus

Venus is still the brightest object in the morning sky and will remain so until it gets too close to the Sun to be seen, later this summer. Staying at magnitude -3.3 for almost the whole of May, and rising about 4:30 local daylight time, you'll have no trouble picking it out in the pre-dawn sky.

On the morning of the 20th, there'll be a conjunction with Mars, when Venus passes about a degree to the south of the ruddy planet. Through a telescope, Mars will be a ball 4.2 seconds of arc in diameter, with 11.3 arc second Venus showing a gibbous phase (90% lit).

Be sure to observe for several days after this, and you'll see a waning crescent Moon approach the pair from the west, passing them by the morning of the 24th.

Asteroid enthusiasts may also want to hunt for the "conjunction" of Venus and Juno on the morning of the 23rd, when Venus will be 3½° to the north of the magnitude 9.5 minor planet.

Moon

First quarter: May 4th, at 04:25 UT, in Cancer. Full Moon: May 12th, at 02:01 UT, in Libra. Last quarter: May 18th, at 23:57 UT, in Aquarius-Capricornus. New Moon: May 26th, at 00:00 UT, in Taurus. Apogee: May 4th, at 22^h UT; perigee: May 18th, at 09^h UT.

Mars

Mars moves from Pisces into Aries during May, and is still rather close to the Sun in the morning sky. There'll be two conjunctions: one with Mercury and one with Venus; both are detailed in the sections on those two planets.

You shouldn't expect to see much of Mars until about July, by which time it'll have moved away from the Sun more and climbed higher above the eastern horizon. The close match in our orbital velocities (Earth's 30 km/sec versus Mars' 24 km/sec) produces a long "stern chase" (as the Navy might say) while we move around the Sun in overtaking Mars.

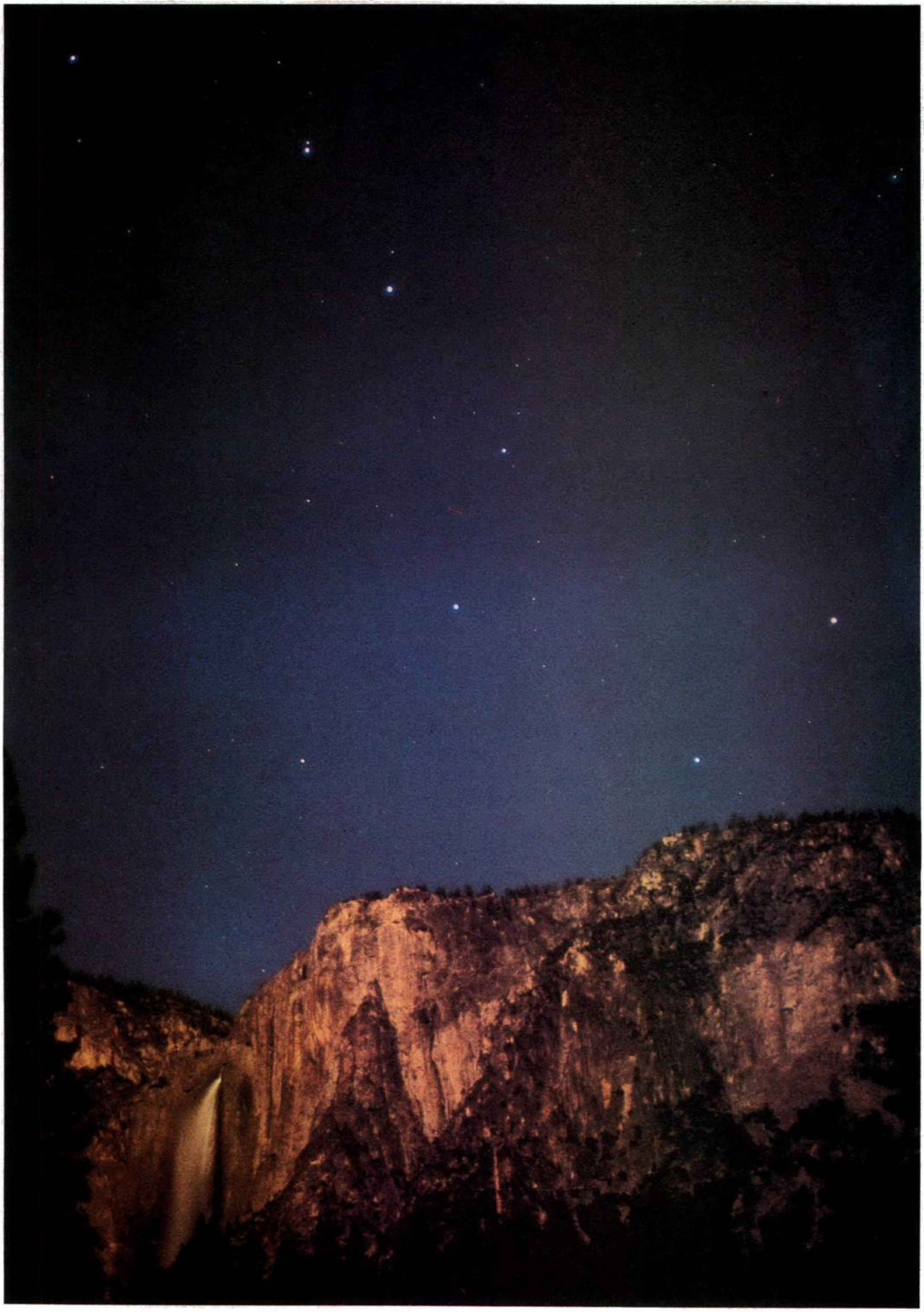
Asteroids

The four brightest asteroids will be found at the following positions (epoch 1950.0) in the morning sky on the 15th. Ceres: $0^h16^m22.7^s$ -8°04′44″, at magnitude 8.5 in Cetus. Pallas: $21^h31^m40.4^s$ +12°09′56″, at magnitude 9.9 in Pegasus. Juno: $1^h59^m06.2^s$ +7°20′22″, at magnitude 9.6 in Pisces. Vesta: $0^h55^m53.3^s$ +0°11′27″, at magnitude 7.9 in Cetus.

Jupiter

May is about the last month to get in a lot of observing time on Jupiter. The planet is setting earlier and earlier each night and by mid to late June, will be an evening object only. On the 15th of May, it transits your meridian at

The familiar shape of the Big Dipper hangs poised in a moonlit sky over Upper Yosemite Falls. Tim Casady took this stunning photograph in July 1978, using a 15 second exposure on Ektachrome 200, push-processed to ASA 400.



Jupiter and M-44, the Beehive Cluster, have been a familiar sight to observers during this recent opposition. Fred Espenak caught the two in late December 1978 with a 6″ f/4 rich-field reflector. He used Ektachrome 400 and a 5-minute guided exposure.

about 5:30 p.m. local daylight time, and sets around midnight.

On that same date, its polar diameter will be 32.9 seconds of arc, while the equatorial measure (larger because of Jupiter's colossal 10-hour spin rate) will reach 35.2 arc seconds. Its changes in apparent size have been gradual, but just 4 months ago, when at opposition, Jupiter's equatorial diameter was fully 10 seconds of arc larger. It will continue to dwindle until superior conjunction (August 13th), when the equatorial size will be down to 31 arc seconds.

Universal Time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

Saturn

On Monday the 7th of May, Saturn's rings will be as widely open as they'll get this year, being just under 7½° inclined to the line of sight. From now until Earth passes through the plane of the rings (on October 27th), we'll be watching the rings gradually close up. Sometime before passing through the plane, the rings will disappear in your telescope. Keep watching as the year progresses and note when they disappear for you.

Titan, Saturn's largest moon, will be at western elongation from the planet on the 6th and 22nd at 5^h and 4^h UT respectively. Eastern elongations happen at 11^h on May 14th and at 10^h on the 30th. You can expect the satellite to be at magnitude 8.5 and the elongations will extend about 4½ ring-diameters from the planet.

Rhea, Saturn's next brightest moon (magnitude 10.5), will lie to the east of the planet on the 3rd, 8th, 12th, 17th, 22nd, and 26th. Western elongations happen in between the eastern ones. The elongation distances are about two ring-diameters from the ball of the planet.

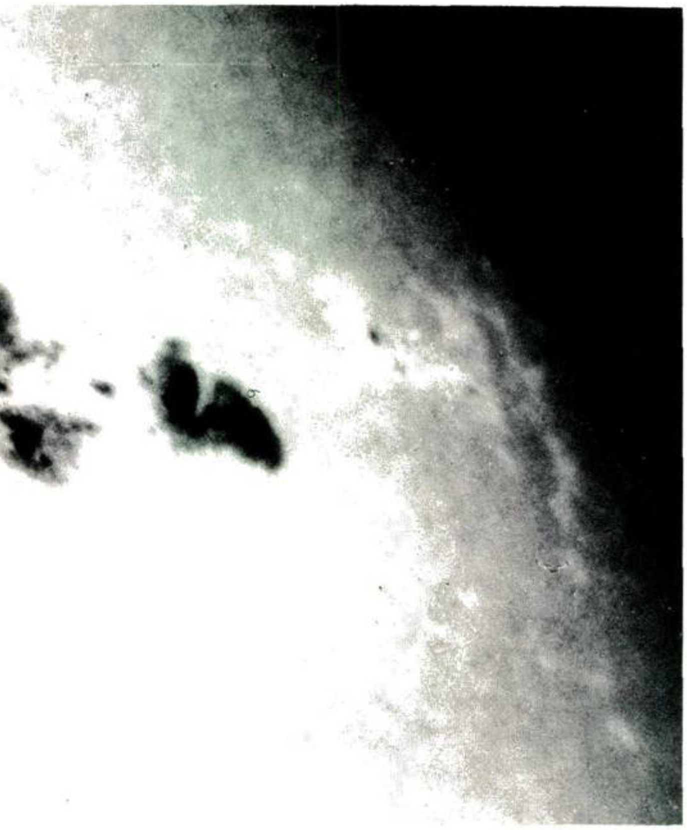
Rhea's period of revolution around Saturn (just over 4½ days) makes the changes rapid indeed when compared to Titan's 16-day period. (The "slow-motion" prize is taken by Phoebe, a 14th magnitude speck at the outer edge of the saturnian system: it has a 550 day period — and it revolves retrograde around the planet.)

M-51, the renowned Whirlpool Galaxy, is in Canes Venatici, but lies 3½° to the southwest of Eta (η) Ursae Majoris, the star at the end of the Big Dipper's handle. Although it can be found in binoculars, at least a 6″ telescope is necessary to pick up the glow of the galaxy's disk under most conditions, and a larger instrument still to catch sight of the spiral structure. This photograph was taken with a 14″ Schmidt-Cassegrain telescope using High-Speed Ektachrome film in a cold camera, with an exposure of 75 minutes at f/7. Photo by Leo Henzl.

See how long you can follow them both, but remember that they're easier to find if you observe for several nights running. Only then can you be sure what points of light are stars and which are moons.

Uranus

Uranus will be at opposition on the 10th of May, at which time it'll be 17.68



As the solar cycle of activity is climbing to its maximum, you can expect to see sunspots and other photosphere features becoming common. Here you see a large sunspot group near the limb, while beyond the group are bright irregular areas known as faculae. Faculae are places where solar activity is more intense, and so, being hotter, they appear brighter than the rest of the photosphere. Jean Dragesco took this photo on Recordak film, using an 8″ Schmidt-Cassegrain and an exposure of 1/250th of a second through a special filter.

AUs (1.6 billion miles, 2.7 billion km) from Earth. You'll find it at magnitude 5.7 as a grey-green dot (3.9 arc seconds in size) in Libra. At the time of opposition, Uranus will be about a degree south of Nu (ν) Librae, a 5.26 magnitude yellowish star.

Uranus now has its northern hemisphere directed towards the Sun (and Earth). Because of the extreme tilt of its axis, 98°, it periodically points first one pole and then the other at the Sun as it circles once every 84 years. This alternate heating and cooling must produce physical effects on the planet which we don't yet fully understand. Perhaps Voyager 2, now preparing for its pass by Jupiter, will be in good enough shape to be targeted on to Uranus after its Saturn flyby.

Neptune

Neptune is now retrograding away from 4.5 magnitude Xi (ξ) Ophiuchi, though all month it will be within a degree and a half of the star. On the 15th, Neptune will be 2½ seconds of arc across, at magnitude 7.8 and will lie at a distance of 29.38 AUs (4.4 billion km, 2.7 billion miles). Light from the planet will take 4 hours 4 minutes to reach us.

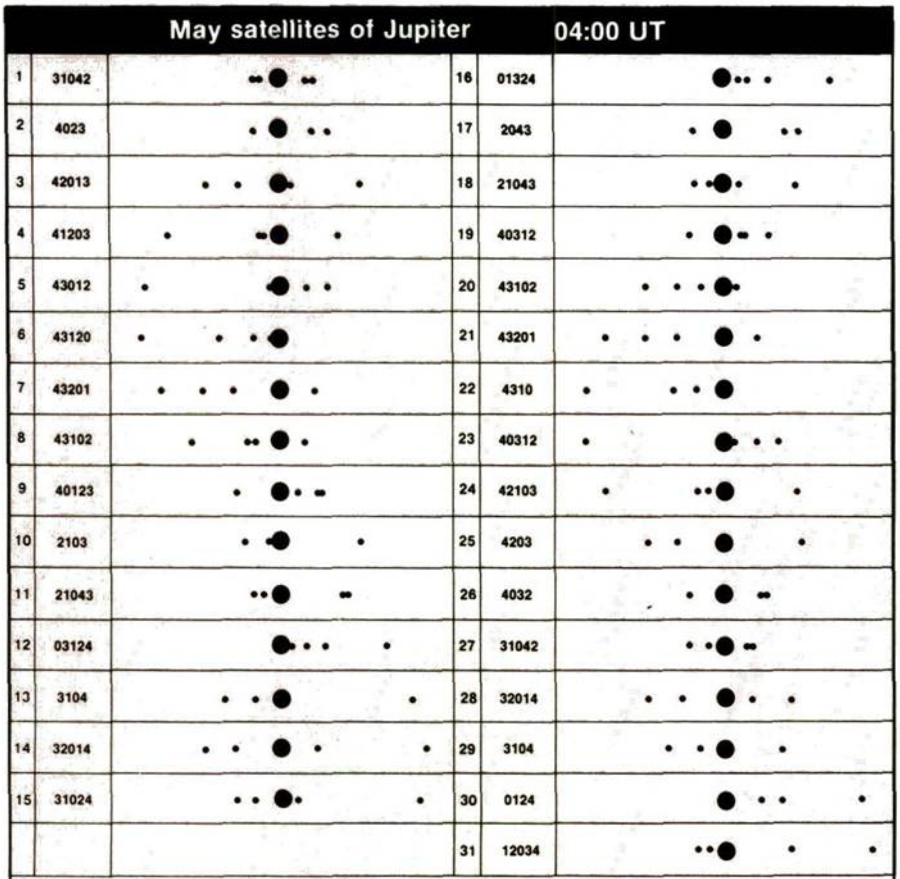
Meteors

The Eta (η) Aquarid meteor shower is the main one for May. The meteors will probably reach their peak of activity on the morning of the 5th, when the Moon will be safely out of the sky.

The shower spends about 3 days with its strength above one quarter maximum rate, so the peak is fairly rapid. The radiant point lies near the center of Aquarius, and rises rather late. The meteors are very swift (65 km/sec), and you can expect about 20 an hour.

The date of maximum seems to be a little variable, so perhaps you ought to start watching for them from the first of the month, or even earlier. (The meteor stream is derived from debris traveling in the orbit of Halley's Comet.)

Other meteor streams this month (both minor) are the Phi (ϕ) Bootids, which are very slow and sparse, peaking on the 1st (radiant: 16^h, +50°); and the Alpha (α) Scorpiids, which are slightly better in both respects and peak on the 3rd (16^h, - 23°).

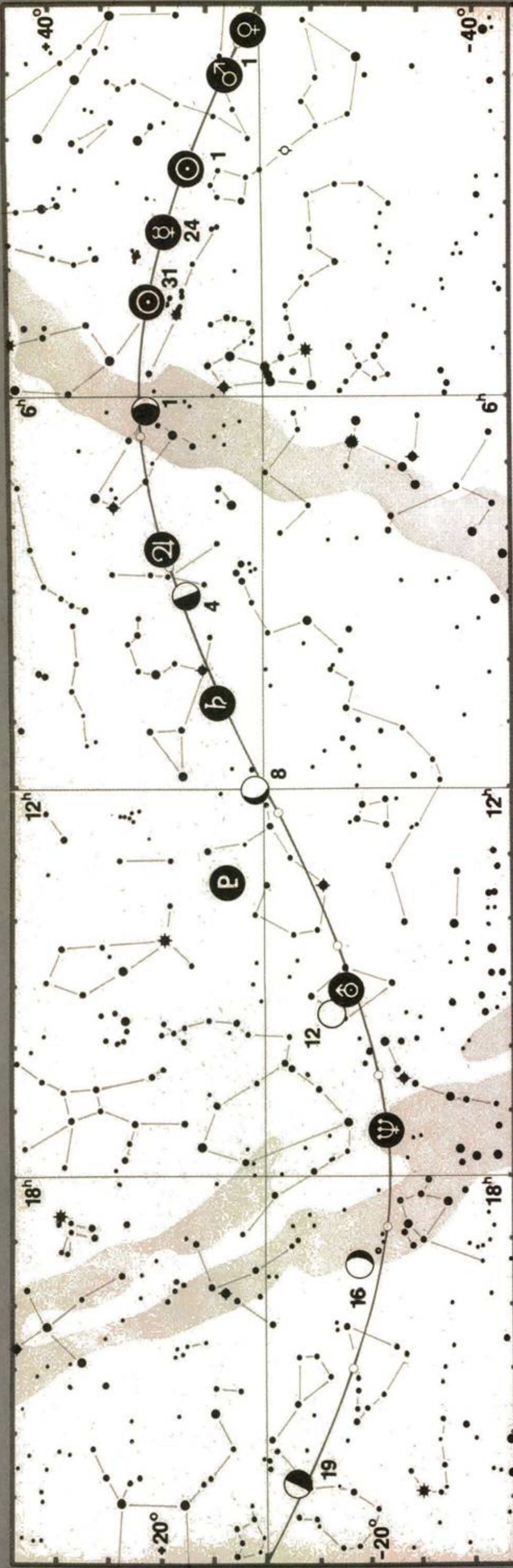


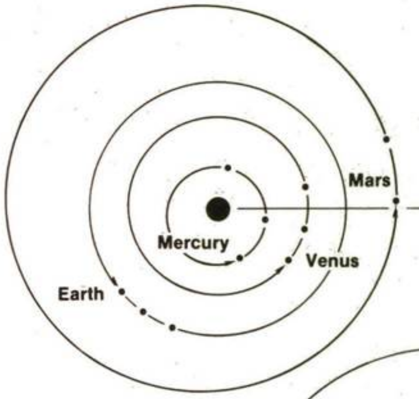
May satellites of Jupiter **04:00 UT**

1	31042	16	01324
2	4023	17	2043
3	42013	18	21043
4	41203	19	40312
5	43012	20	43102
6	43120	21	43201
7	43201	22	4310
8	43102	23	40312
9	40123	24	42103
10	2103	25	4203
11	21043	26	4032
12	03124	27	31042
13	3104	28	32014
14	32014	29	3104
15	31024	30	0124
		31	12034

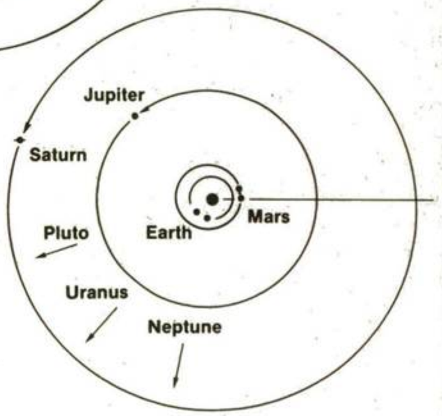
The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = I, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

Planet Finder


+40°
-40°
1
1
24
31
6h
1
4
8
12h
12
16
18h
19
+20°
-20°

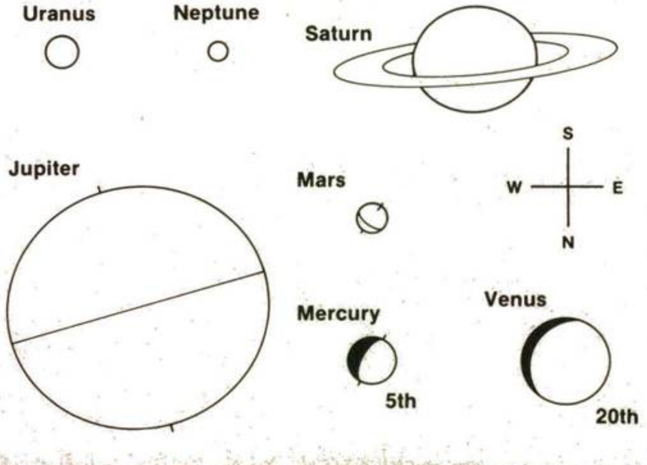

Mars
Mercury
Venus
Earth

The positions of Mercury, Venus, Earth and Mars in their orbits are shown for the beginning, middle and end of the month. (Mars for the beginning and end only). The vernal equinox is the line at right.

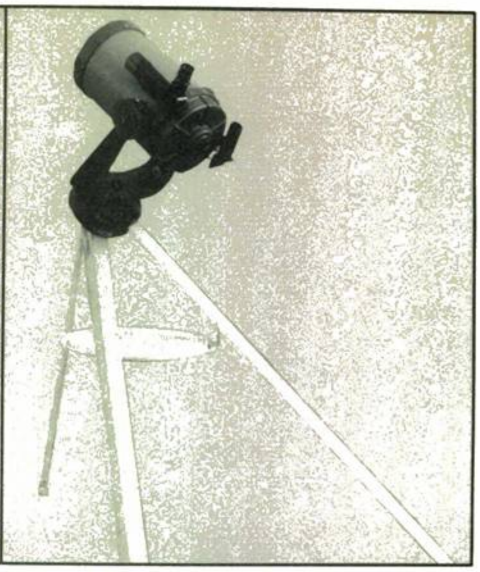

Jupiter
Saturn
Mars
Pluto
Earth
Uranus
Neptune

The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for mid-month. The outermost planets' directions are indicated.

Planet	Date	R.A. (1979.4)	Dec.	Mag.	Dist. (AU)
Mercury ☿	5	$1^h20.0^m$	5°26.5′	+0.1	1.06
	10	$1^h49.3^m$	8°38.6′	-0.3	1.13
	15	$2^h22.0^m$	12°08.0′	-0.7	1.21
Venus ♀	10	$1^h17.6^m$	6°21.0′	-3.3	1.43
	30	$2^h50.0^m$	14°47.4′	-3.3	1.53
Mars ♂	15	$1^h49.3^m$	10°30.1′	+1.5	2.26
Jupiter ♃	15	$8^h20.3^m$	20°13.3′	-1.6	5.59
Saturn ♄	15	$10^h38.2^m$	10°43.2′	+0.9	9.06
Uranus ⛢	15	$15^h05.7^m$	-17°04.8′	5.7	17.68
Neptune Ψ	15	$17^h16.1^m$	-21°36.1′	7.8	29.37
Pluto ♇	15	$13^h27.8^m$	9°46.3′	14.0	29.47


Uranus
Neptune
Saturn
Jupiter
Mars
S
W
E
N
Mercury
5th
Venus
20th

SUPER GIANT RICH-FIELD FINDER
Giant Rich-Field Finder on C-8.



C-8 on A NEW ISOSTATIC EQUATORIAL MOUNT with ACCESSORY TRAY

We continue to make the best better.

Every SUPER CELESTRON 8 we sell not only comes equipped with our FREE GIANT RICH FIELD SUPER FINDER but now can be supplied with our NEW ISOSTATIC EQUATORIAL MOUNT.

This sturdy, stiff, vibration-free, stable support folds up for compact storage. It has a simple one-hand latitude adjustment from 25-55 degrees and functions as both a wedge and a tripod. It needs no tools and can easily be fitted with a convenient accessory tray.

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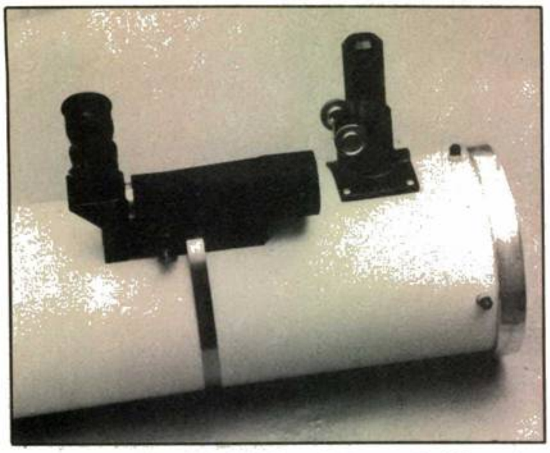

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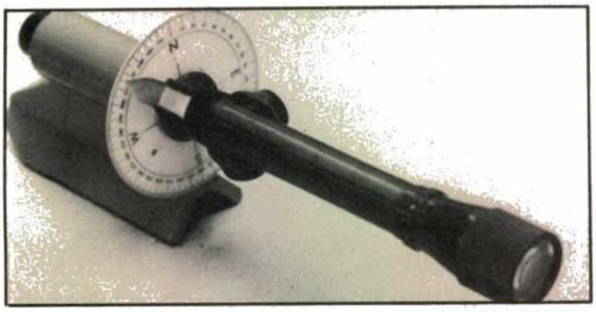

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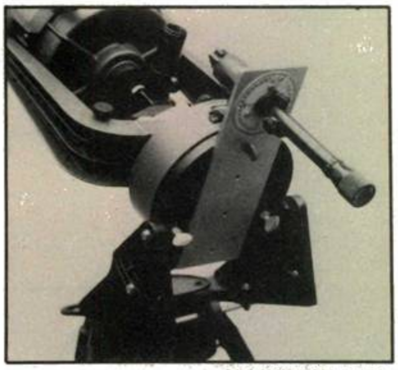

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ECLIPSE SPECIAL

The Great Midwinter Eclipse

by

Dan Koehler

The February 26, 1979 total solar eclipse is now history, but for the thousands of observers and "eclipse buffs" who lined themselves up along the wide path of totality in the U.S. and Canada, the event will live in vivid memory for years.

Despite poor weather prospects, the favored sites in the U.S. were jammed with observers from all parts of the country. Goldendale, Washington, home of the world's largest public observatory, became a haven for throngs of viewers, especially those living west of the Rockies. They came in vehicles of all descriptions — cars, trucks, buses, trailers, and campers.

Roads in the area, as well as other thoroughfares all along the path of totality, became clogged with people rushing frantically here and there at high speeds, trying to take advantage of large holes in the prevailing moderate-to-light cloud cover. As the magic moment of totality arrived, everywhere you looked, telescopes and cameras pointed skyward to glimpse and record the event.

Likewise, observers in eastern Montana and northwestern North Dakota were provided with observation sites near the center line of the eclipse track. But a lot of worried faces were seen over the weekend as most of the area was socked in by dense clouds. Miraculously however, the sky improved on Sunday evening, and Monday morning dawned relatively clear. Some high cirrus interfered slightly with the partial phases, but by the start of totality, not a cloud could be seen in the east and south. Eclipse time temperatures ranged from 32° to 40° Fahrenheit; a more perfect day couldn't have been asked for.

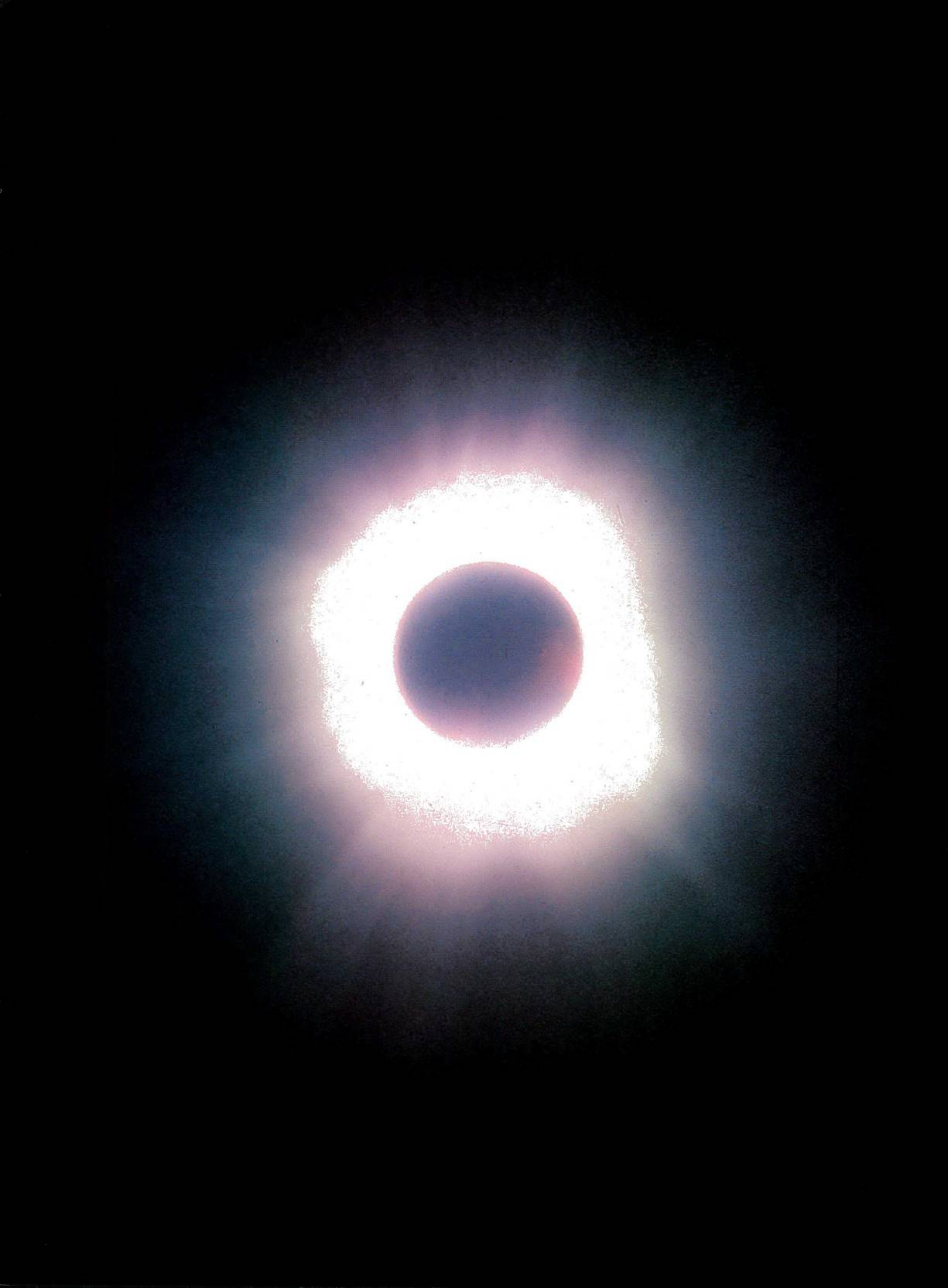
Slightly colder temperatures predominated in southern Manitoba, but viewers there were treated to the spectacle all the same. Skies in Canada cleared early Sunday afternoon, though high cirrus hampered the view a little on Monday morning. Like their U.S. counterparts, residents of Brandon, Portage-la-Prairie, Winnipeg, and other Manitoban cities and towns enjoyed the day with thousands of eclipse enthusiasts from all over.

And just what did those who came see? The Sun's corona, the traditional "show-stopper" of all solar eclipses, performed well up to expectations, radiating uniformly around the Moon's dark limb. Its pearly luster and numerous streamers reminded many of an icicle structure lit from behind. One veteran of five eclipses remarked after this one that the corona was the prettiest he'd ever seen. Several people noted the knotty appearance of parts of the corona, especially one that resembled a figure 8, shown well in the photo by John Cade on page 43.

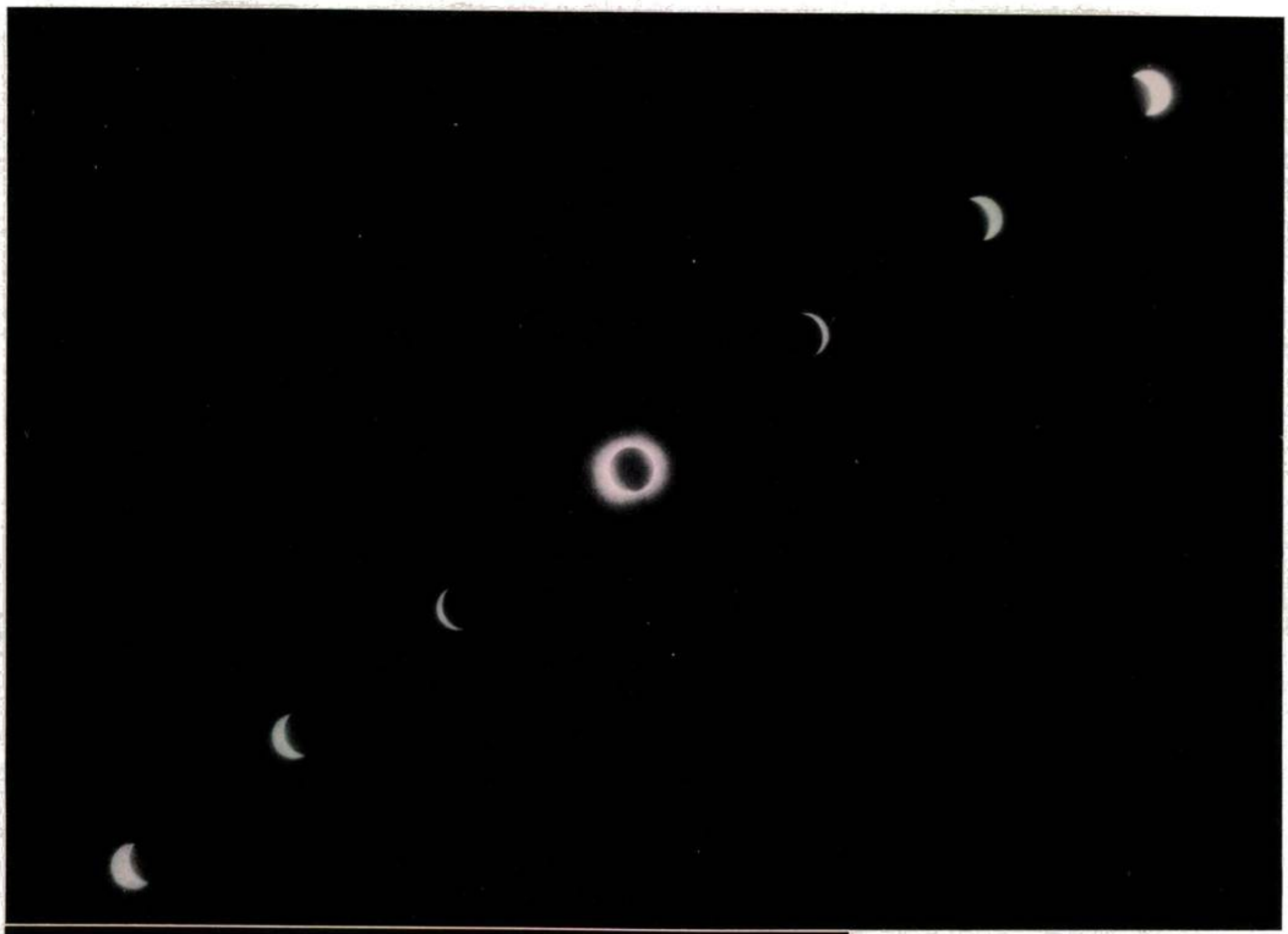
The corona was also "impatient" in a way since it began to emerge from the partial phases fully 10 seconds before totality actually commenced. Anguished cries arose as some viewers were caught unprepared. Four very outstanding prominences glowed redly at the 2, 4, 7, and 10 o'clock positions around the lunar limb. Since this eclipse happened close to sunspot maximum, the corona was relatively circular in overall shape. The planets Mercury and Venus were seen easily by many people, but Mars was more elusive, perhaps because it was closer to the bright corona.

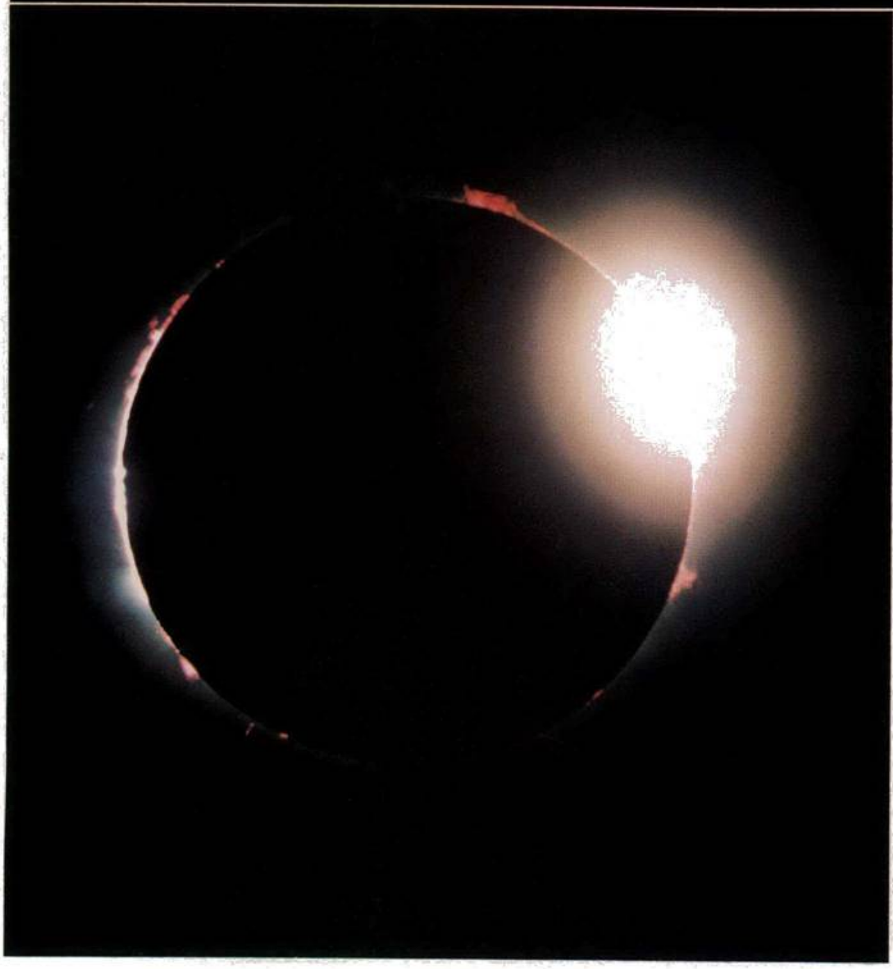
During totality, camera settings could be read easily, and land features both near and far were seen distinctly. Many felt that this eclipse wasn't as

A full expanse of the solar corona flows outward in streamers from the dark occulting disk of the Moon, thus corresponding to most viewers' visual impressions. Ben Mayer used a 500 mm lens at f/4.5 with an exposure of 1/15 second on Ektachrome 400. He was in an airplane 32,000 feet over the Idaho/Montana border at the time.



The end of totality draws near with the western edge of the Moon's shadow approaching from the right in this picture taken near Williston, North Dakota. The eclipsed Sun is to the upper left, while level with it at the right-hand edge of the frame is Venus. Glenn Lambert used a 28 mm lens and Ektachrome 64 for 1 second at f/16.





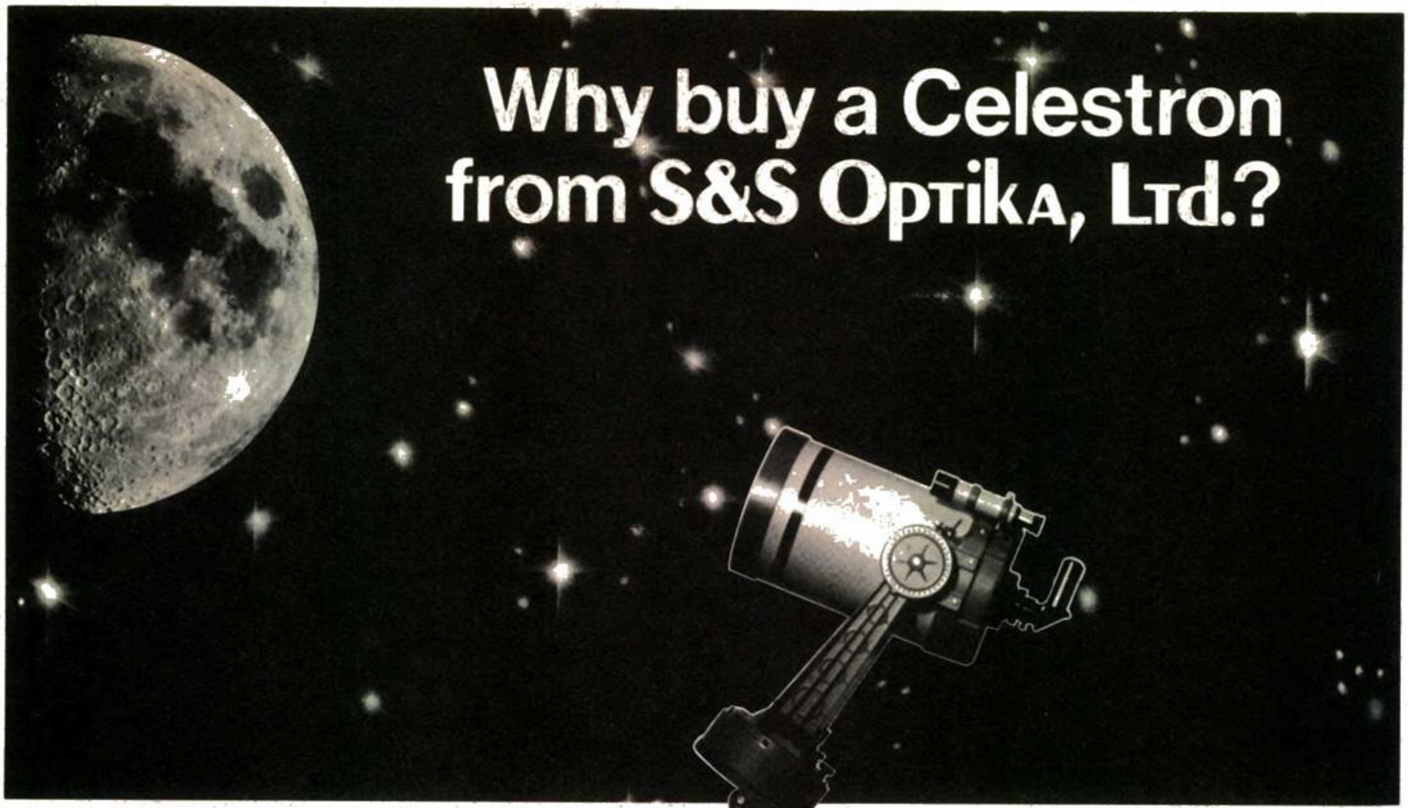
Above: Careful planning beforehand enabled Thomas Young and Richard Rosenthal at Lewiston, Montana to get this series of partial phases framing totality onto one sheet of film. They used a 4 x 5 press camera with a 127 mm lens on Plus-X. The exposures were at 10 minute intervals, the partial phases using 1/400 second at f/16, totality needing 1/4 second at f/5.6. Below: Jim Rouse was near Bowbells, North Dakota when he took the 3 frames that went into this composite photograph showing a pretty diamond-ring effect. The exposures were with a Celestron 5 on Kodachrome 64 and the time was 1/25 second.

dark as some, but since it came at a time of year when the snow-cover on the ground was ample, the bright illumination shouldn't have been surprising.

Most observers located in the totality path noticed their horizons, especially to the southeast and northwest looked salmon pink. This came about from the dim sunlight falling on the land outside the path of totality — you could actually tell that you were standing in a narrow band of darkness surrounded on both sides by light.

Another aspect of the eclipse that surprised many viewers was the slow pace of the encroaching darkness

ECLIPSE *continued on page 43*



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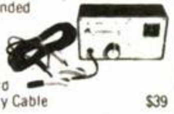

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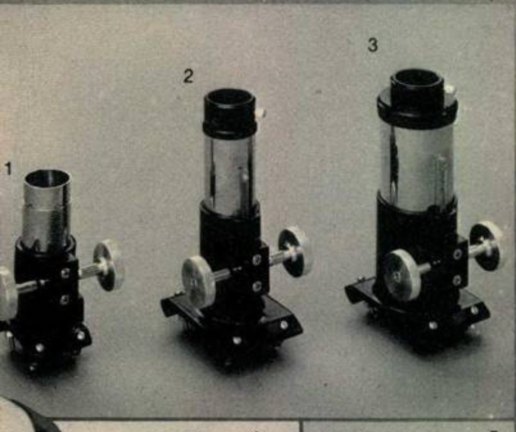

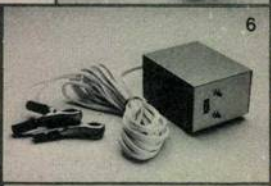

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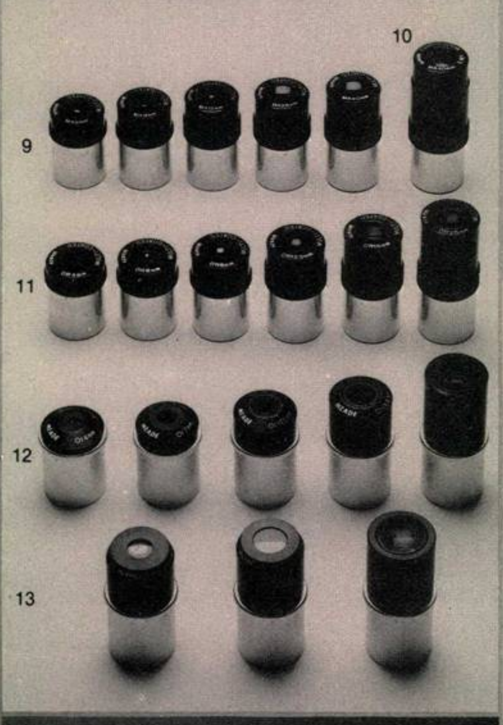

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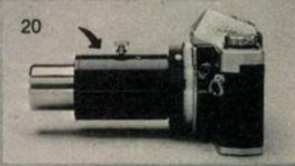

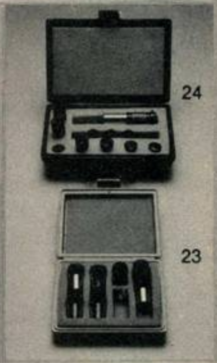

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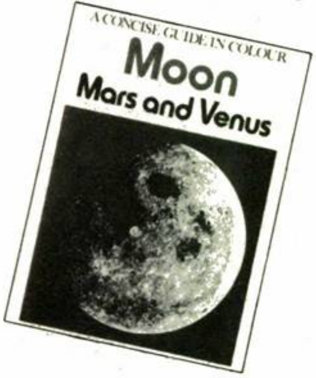
ASTRONOMY'S BOOKSHELF

FOR THE SUMMERTIME OBSERVER

Moon Mars and Venus



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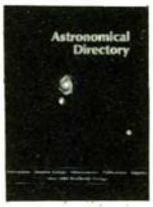

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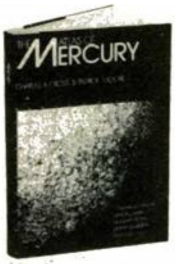

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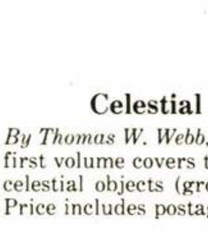

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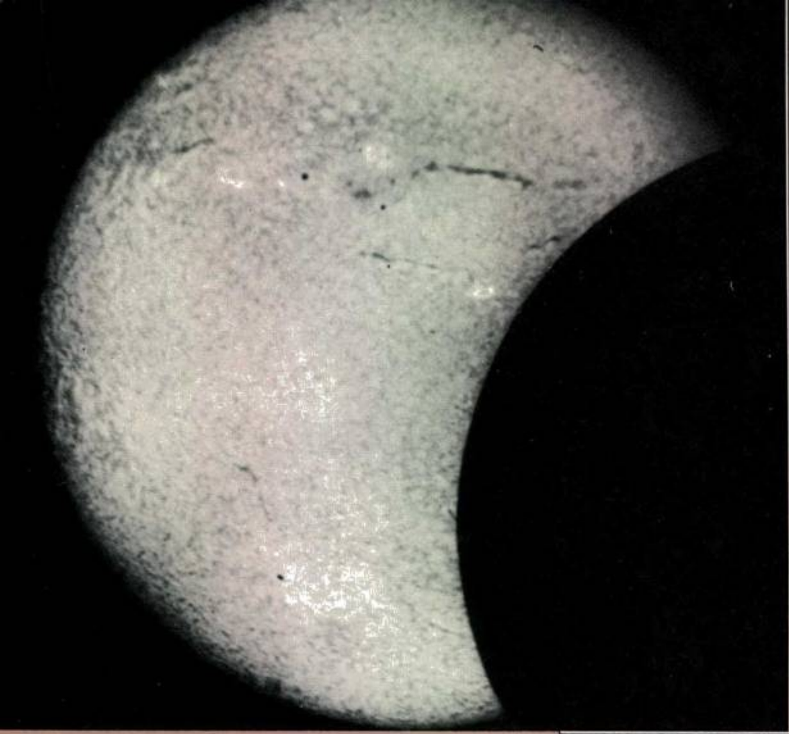
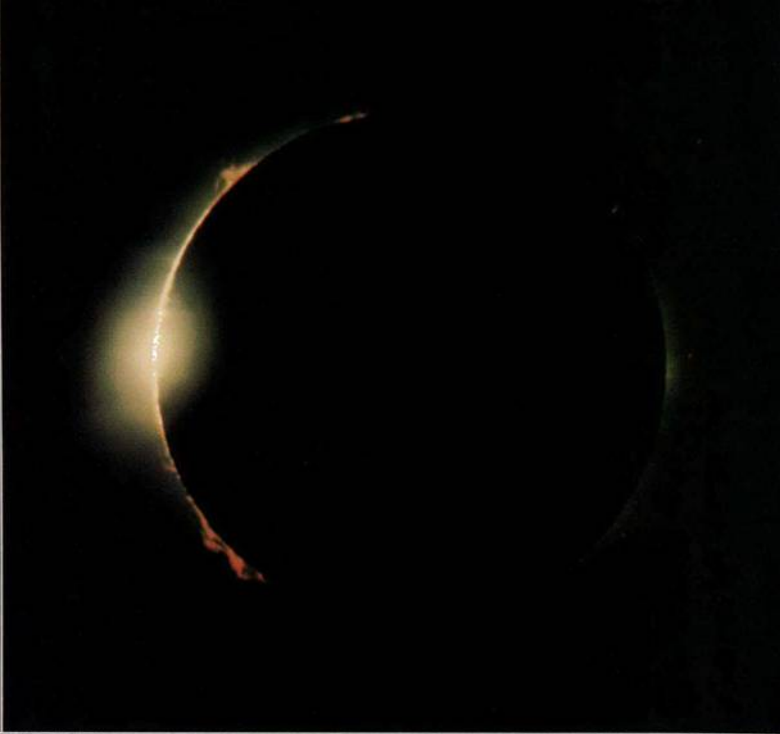




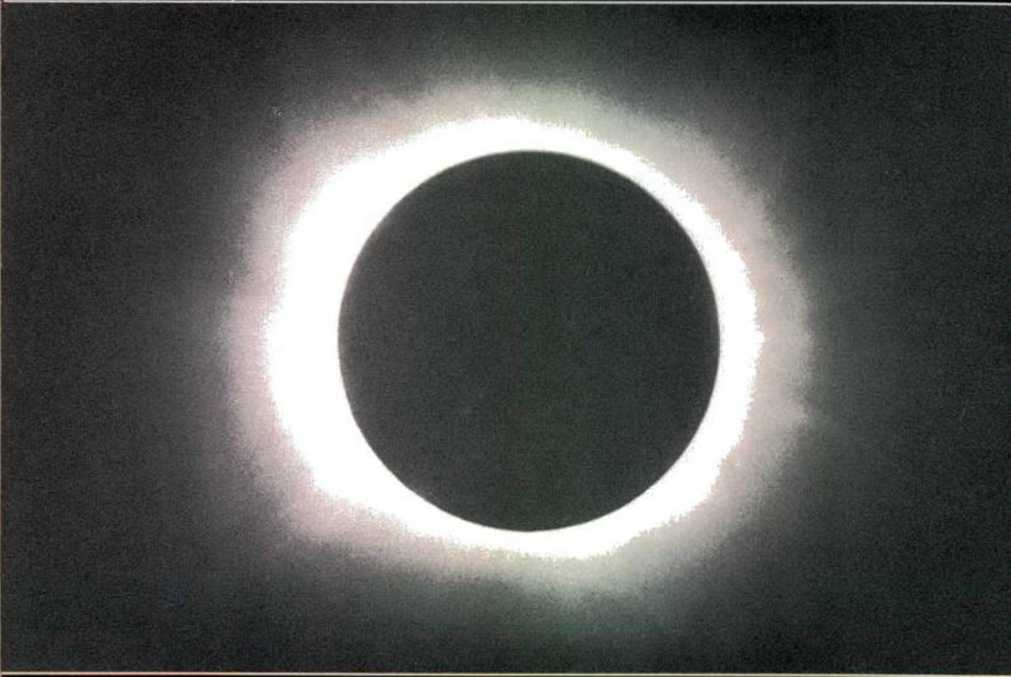
ECLIPSE

continued from page 38

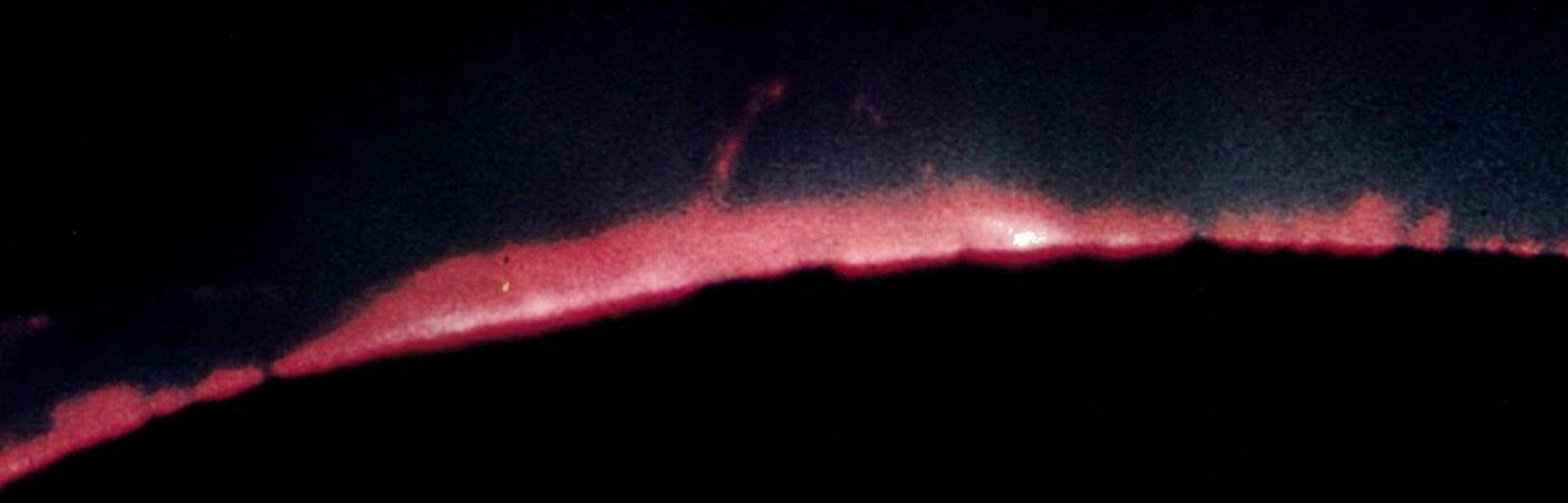
during the early phases. People watching their first eclipse remarked that they had imagined their surroundings would become dark rather quickly. But darkness wasn't really evident until about 10 to 15 seconds before the onset of totality. When the darkness finally was noticeable however, it really did get dark — and fast. The color of the sky changed quickly at this point from the familiar blue to a very deep indigo.

As the Moon's shadow swept over the land from the west, the sudden arrival of dark totality made many observers want to duck out of the way or gasp with amazement. Many seemed more entranced with the eclipse's effects on their environment than in viewing the event itself. People who lived in the path of totality were surprised how long-familiar land features took on strange and unfamiliar shapes in the eerie light.

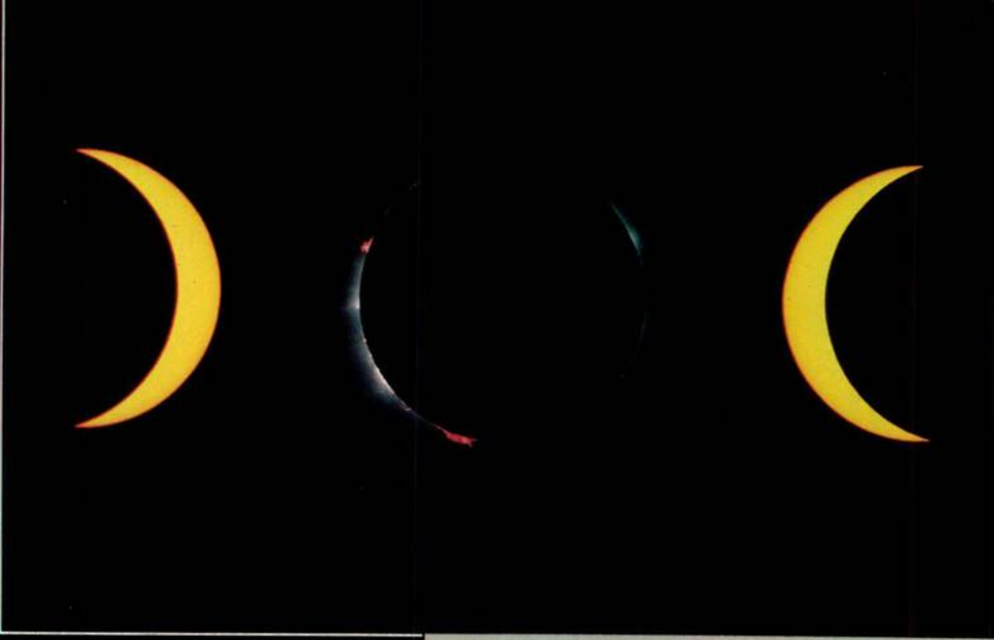
At its conclusion, the eclipse was topped off with a gorgeous "diamond-

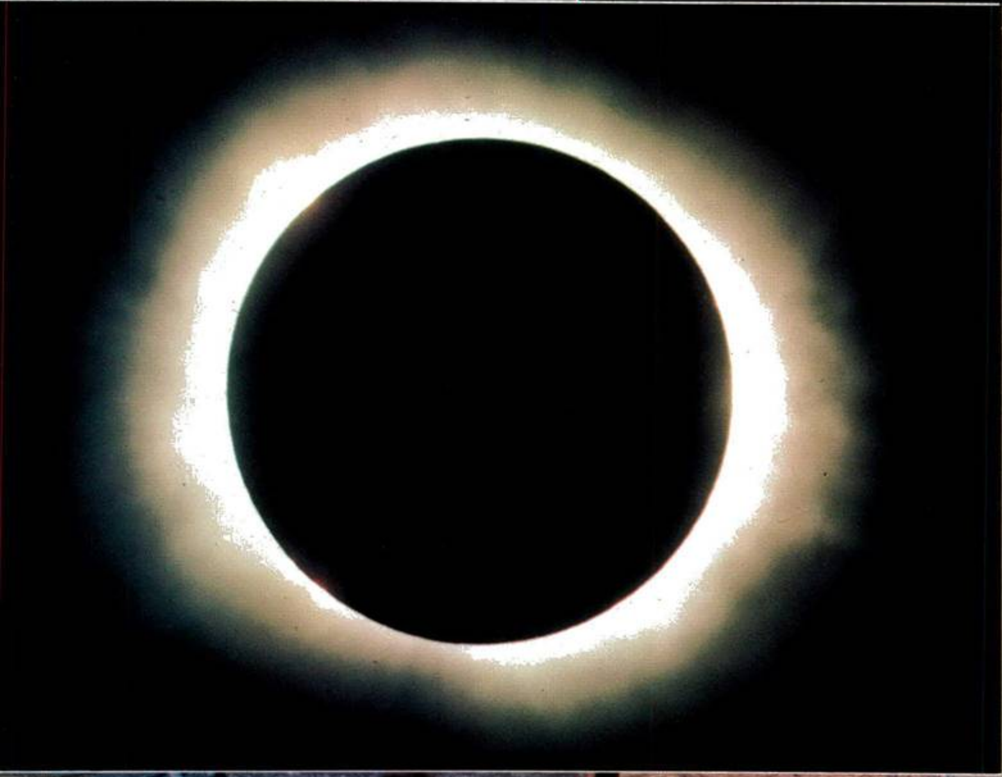


Above: David Hahn, near Portage-la-Prairie, made this shot of the partially eclipsed Sun through a filter that lets in light only at 6562 Angstroms, the wavelength of hydrogen-alpha. Upper right: The diamond-ring and several prominences stand out well in this photo taken by Michael Marcario from Helena, Montana. He used a 10" f/6 homemade Newtonian and Ektachrome 400. Right: John Cade's black & white photo reveals much of the unusual structure in the inner corona that was noticed by many observers during the eclipse. The exposure was 1/8 second with Plus-X through a Celestron 8 using a focal reducer. Bottom right: From Winnipeg, William Brunner recorded inner corona with a 1250 mm f/10 telephoto on Ektachrome 400. The exposure was 1/125 second.



Jacques Guertin's observing site was 30 miles north of Minot, North Dakota. In this magnificent photograph, the great prominences that were star attractions stand out in bold array along the limb of the Moon. He used a Quantum 6 at f/16 and Kodachrome 64, with 1/30 second exposure through thin clouds. Inset left: William Brunner's shot shows a moderately full corona. Data the same as for his photo on the previous page, except the exposure was 1/30 second. Inset right: Short exposures recorded prominences and the innnermost and brightest parts of the corona. Paul Severance was at Minot and took the photo with a Criterion 6″ f/8 on Ektachrome 200 using 1/250 second.





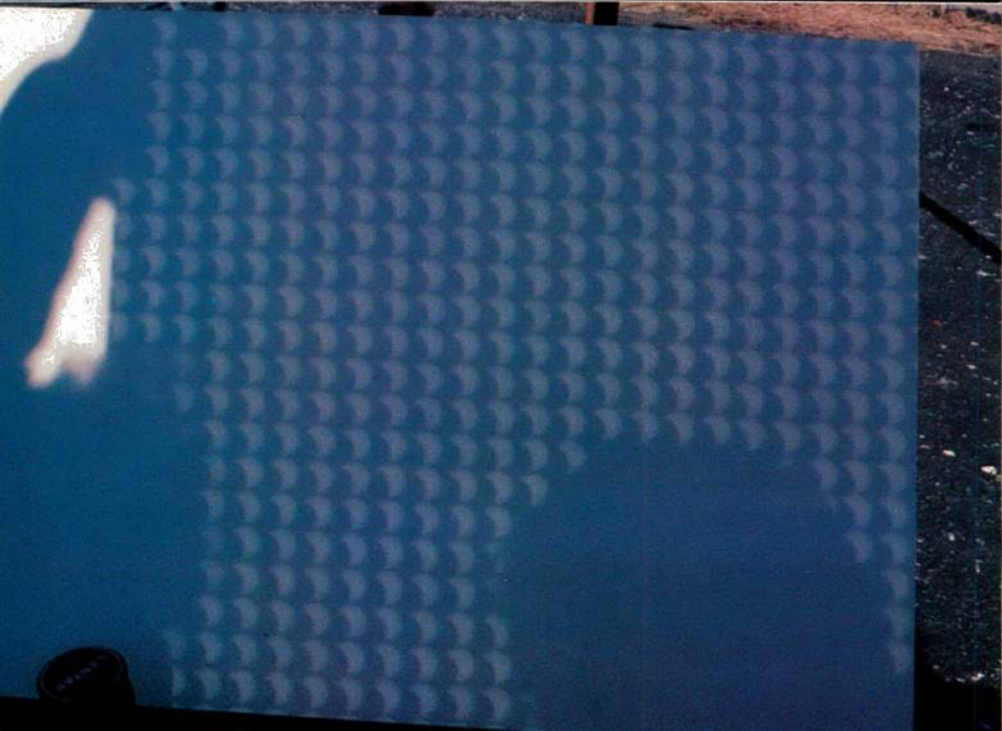
Above: Jim Rouse did some darkroom work to produce this composite showing the late partial phases framing a totality shot showing prominences and inner corona. Upper left: Bob Kimmel took this from Riverton, Manitoba through a 3″ f/5 objective using a #5 neutral density filter. Exposure was 1/125 second onto Kodachrome 64. Left: Michael Marcario shot this from his site in Helena. Photo data same as for picture on page 43. Below left: Valentine Germann cleverly used a piece of pegboard to make a multi-pinholed projector.

ring," a result of solar light streaming through gaps between mountains on the lunar limb. The phenomenon hadn't been as evident at the commencement of totality as at the end, and for many it proved to be a perfect finishing touch to a fine eclipse.

For the astronomers who came to the eclipse, much work remains to be done before they can evaluate fully the scientific results, but for the thousands of viewers who live in the path or traveled great distances to photograph or just to watch, the results are already tallied. "Spectacular!" "Beautiful!" "We made it!" "Magical!" These only begin to describe how the eclipse impressed its onlookers. Was it worth all the preparations, planning and hassles? The answer from all who attended is a resounding "Yes."

Some will be content to remember forever how the Great Midwinter Eclipse impressed them — how their lives were changed ever so slightly by being at one of Mother Nature's timelessly beautiful events. Some will have been reminded that they're an integral part of a vast intricate system.

But for others, eclipse chasing has become a passion for which there's no easy cure. You could almost hear the shouts of "See you in Mexico in '91," or among the more affluent, "See you in India next year," as this beautiful eclipse faded into memory.



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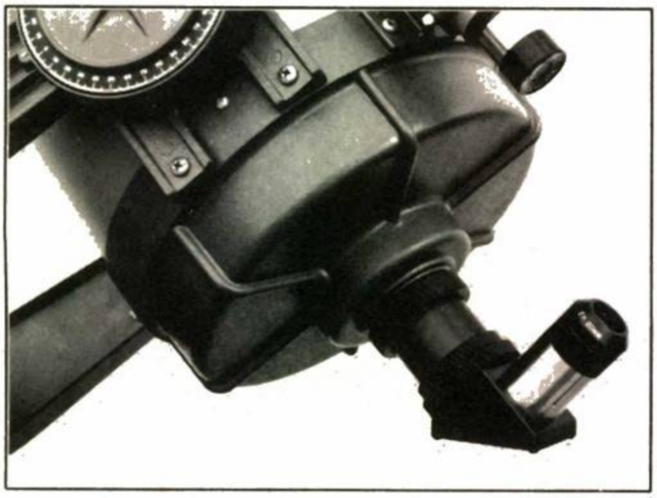

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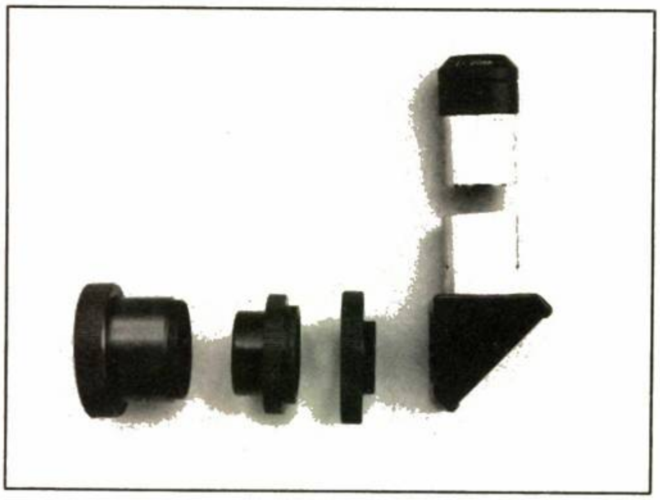

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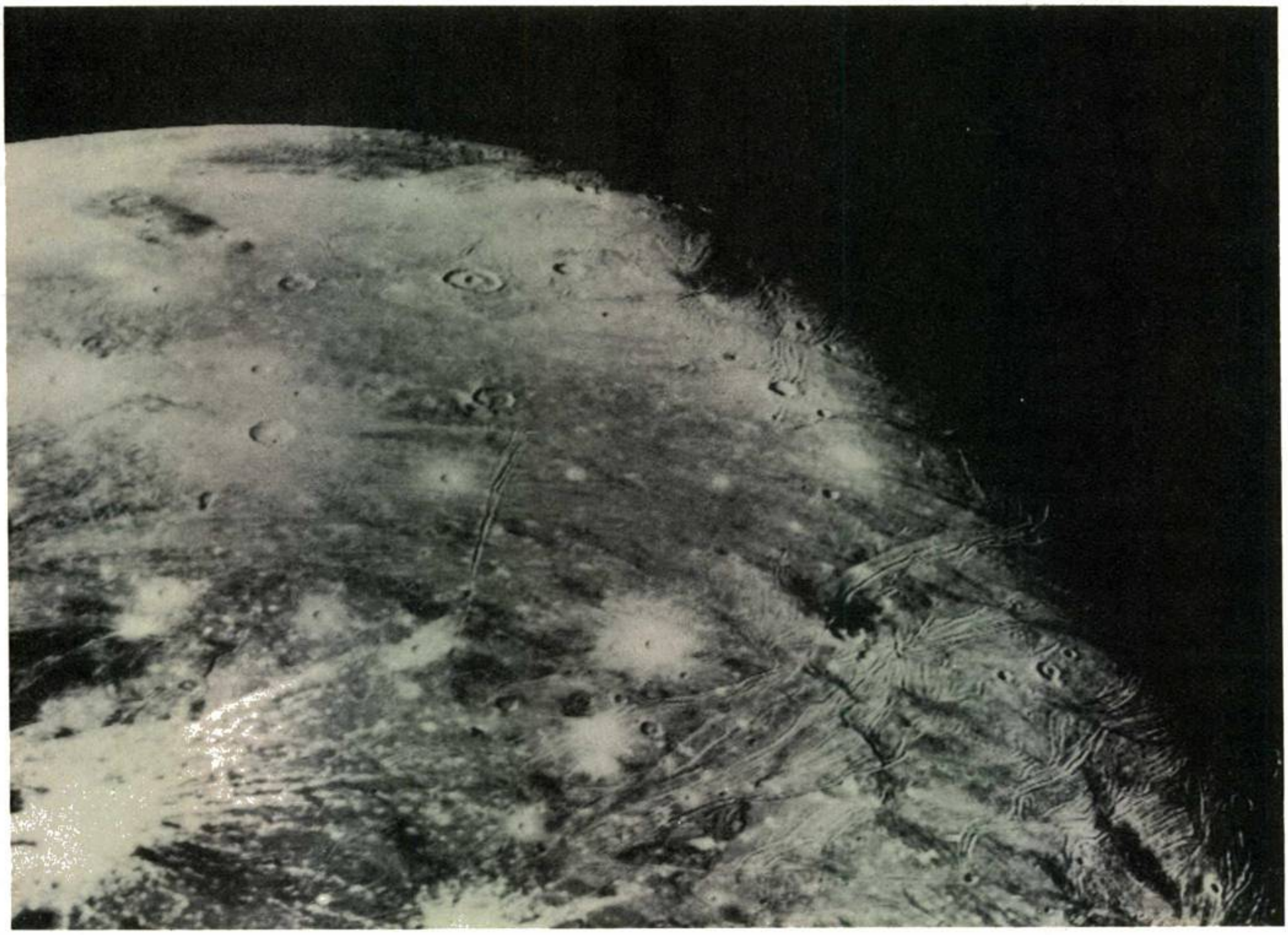


The smallest features visible in this photograph of the surface of Ganymede are about 3 miles across. Impact craters dot the surface, and many show ray systems probably consisting of icy material thrown out by the impacts. The peculiar sinuous ridges ("dune-buggy tracks") and grooves that traverse the surface are probably the result of deformations in a thick ice crust. Photograph from JPL/NASA.

JUPITER *continued from page 23*

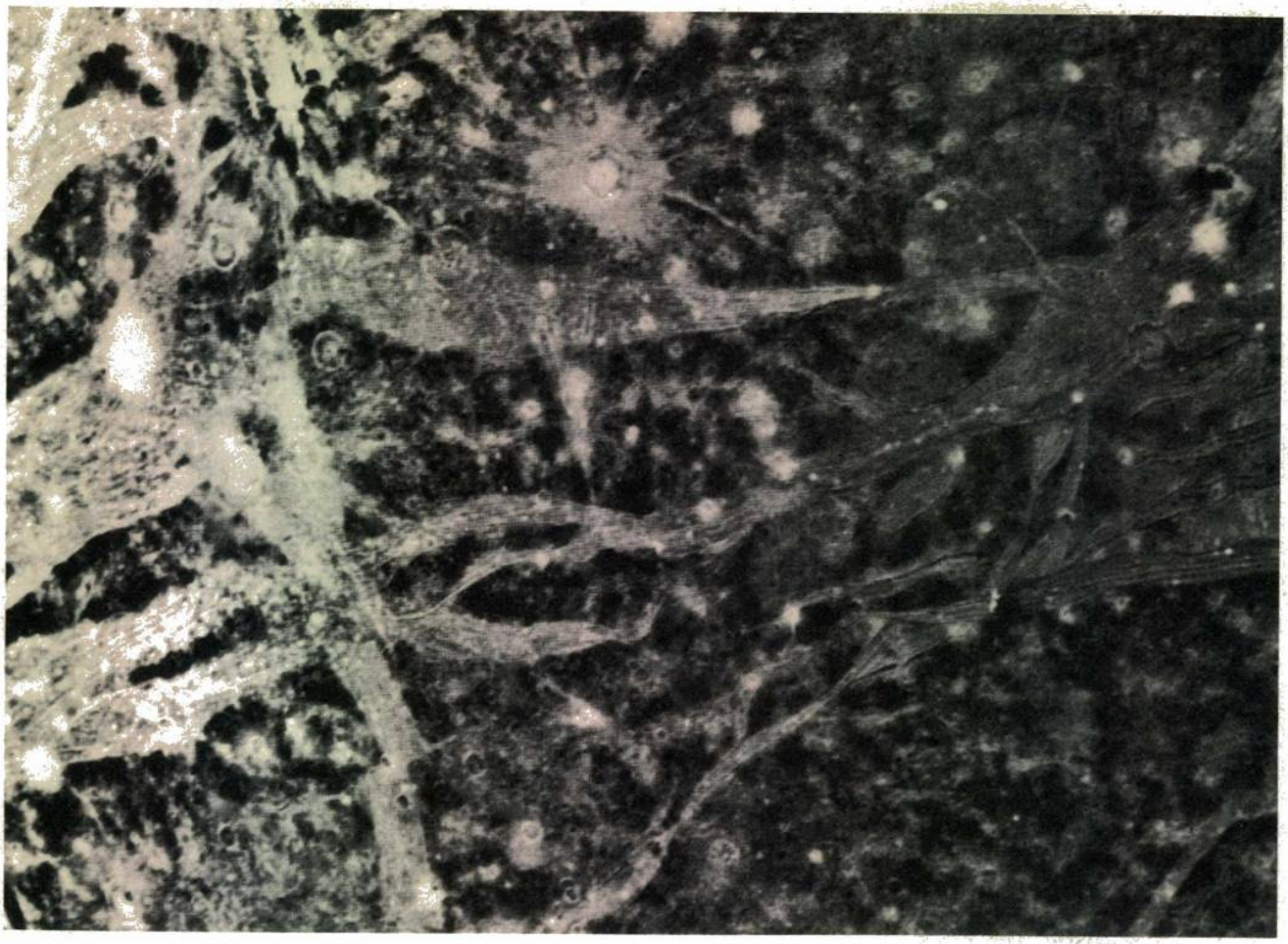
moons. Outside the rigidly rotating disk, the particles flow outward from Jupiter — a miniature analog of the solar wind.

But it's in the region of Io's orbit that we find the most peculiar features of the jovian environment. Here, the density of the plasma rises quickly to a maximum, and a plasma torus, or "doughnut," completely encircles the giant planet. The tube of the torus is as large as Jupiter is wide. Inside the tube, the plasma density increases toward the center. Io's orbit lies within this torus, though not right at its center, because Io's path follows the equatorial plane of Jupiter's rotation, while the torus is oriented exactly in the equatorial plane of Jupiter's magnetic field. So as Jupiter rotates, the plasma torus wobbles around, dragged by the slightly tilted magnetic equator. Io, therefore, weaves a complicated path inside the torus, moving up and down inside its tube.

We knew this doughnut ring of particles existed before we went to Jupiter, but now that we can observe it close-up, several surprises emerge. We knew that it contained singly-ionized sulfur ions (that is, those that have lost one electron), at a density of about 50 ions per cubic centimeter. But now we discover an enormous number of *doubly*-ionized sulfur ions (from which *two* electrons have been stripped away) — 500 of them per cubic centimeter. And instead of the expected cool plasma at a temperature of 10,000° Kelvin, we find it much hotter: 100,000° K. This means that something pumps 500 billion watts of power into the torus — yet we have no idea where that much energy could be coming from.

An even stranger feature of Jupiter's nearby environment is Io's flux tube. This tube is a concentration of magnetic lines of force coming from Jupiter's magnetic poles and passing through the body of Io. Through it must flow an enormous current, or flux, of electrons. Voyager, as it passes under the south pole of Io, flies directly through the flux tube. Although the magnetic and electrical effects are observed as expected, the large flux of electrons is absent. What happened? Did Voyager just miss the main current, or is something wrong with the theories? It's another puzzle for the planetary scientists to work out in the coming months.

Finally, in the region closest to Jupiter where the magnetic lines reach down to the north and



Ganymede's fascinating patterned surface is seen here in close-up. The frame is about 600 miles on a side, and the smallest features represented are about 1.5 miles across. Bright bands visible in photographs of the whole planet turn out to be intricate systems of alternating light and dark lines which may represent the deformations of a thick, icy crust. One bright band in the lower left is offset along a bright line, showing that the surface has faulted. The surface displays many impact scars with bright ray systems. Photograph from JPL/NASA.

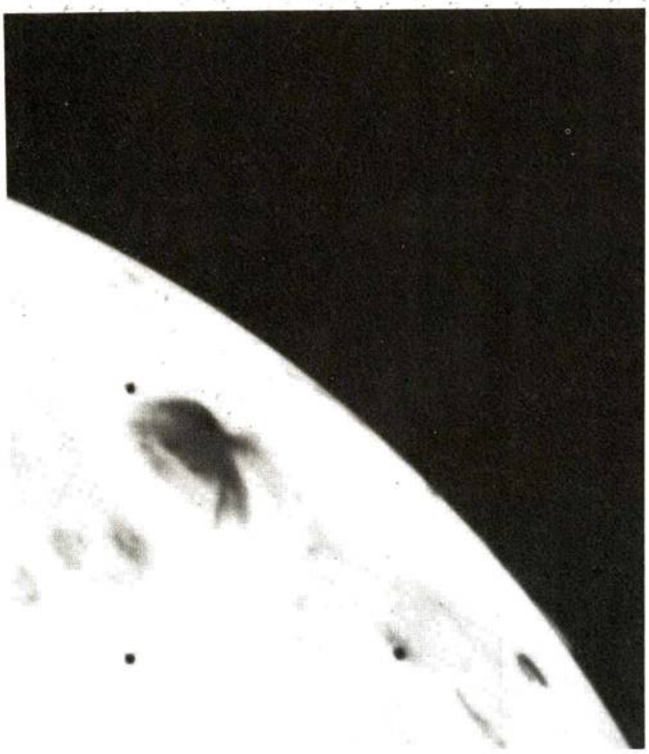
south magnetic poles, we discover strong auroral emissions from both polar regions. Jupiter, it seems, has particularly intense northern and southern lights. And although we expected to find an extended ionosphere with a temperature of about 850° K, on the basis of the earlier Pioneer missions, we find that it's more extended, with two separate regions, one at 900° K and another at 1500° K. Below the ionosphere, less than a thousand miles above the visible cloud deck, the electrons seem to form into definite layers.

As the far encounter draws to a close, the excitement and anticipation mounts. Voyager is now deep within the radiation-filled environment of Jupiter, with the giant planet now filling 20° of the sky outside, its huge flattened disk 40 times wider than the full Moon seen from Earth. It will swell to more than 24° across at closest approach, but then we'll be behind Jupiter, and the giant planet will appear only as a wide cresent.

Near encounter phase is upon us at last — 546 days of crossing space for a flyby lasting just 39 hours. The most intensive phase of observation and measurement now begins: the automatic, pre-programmed computer switches quickly from instrument to instrument, recording data and playing it back to Earth at the highest rate possible.

About 18 hours before closest approach, one of the most remarkable findings of the mission is made. As the spacecraft crosses the equatorial plane of Jupiter — and at the exact moment the spacecraft is in the plane — a single 11-minute time exposure is taken. The scientists involved in mission planning were divided on whether such a photograph was worthwhile, but they had finally decided to try anyway. All agreed that finding a ring was unlikely. But right from the moment the picture was received, it was obvious that something interesting had been recorded. The Voyager scientists were lucky enough to record its outer edge, thus showing that the outer edge of the ring lies at a distance of about 35,500 miles from the surface of Jupiter. (If the middle of the ring had been photographed, we wouldn't know how big it is.) The ring is no more than 18 miles thick, and is probably at least 5000 to 5500 miles wide. Voyager 2 will attempt more pictures of the ring — in greater detail — in a few months.

Attention now shifts to Jupiter's satellites. We've studied the atmosphere and dynamics of



This photograph of a volcanic eruption on Io was taken March 4, about 11 hours before Voyager's closest approach to the jovian moon, from a range of 304,000 miles. The brightness of the plume has been computer-enhanced in this image, but the greenish color of the plume and the yellow-orange of the surface are correct. Solid material, ejected from the volcanic vent at approximately 1200 miles per hour, is being thrown up to an altitude of about 100 miles in this picture. The area around the vent is a complex circular structure consisting of a bright ring about 200 miles in diameter and a central region of irregular light and dark patterns. On Earth, similar volcanic explosions occur when magmatic gases expand explosively out of molten rock vented from the ground; here, however, water is the major gas driving the explosion. Io is thought to be extremely dry, so scientists are seeking other gases to explain the eruption. Photos from JPL/NASA.

Jupiter itself, and begun to examine in detail the physical environment of this strange system. The third goal of our mission still lies before us: a close-up study of the jovian satellites. (These encounters all occur after the closest approach to Jupiter, which comes at 4:42 a.m. P.S.T. on the morning of March 5, 1979.)

As the mission progresses, a curious thing happens: the scientists start calling the satellites "planets." Laurence Soderblom of the U.S. Geological Survey, a member of the Imaging team, says quite unequivocally that on the basis of their size and diversity, "they belong to that set of things called planets."

The satellite closest to Jupiter is tiny Amalthea, discovered in 1892 by E.E. Barnard. Our closest approach, at a range of 260,000 miles, occurs just before closest approach to Jupiter itself. The cameras reveal it to be an irregular, elongated object, with its long axis permanently locked by gravitation toward Jupiter. "It's a brick!" says one of the project scientists, referring to Amalthea's lumpy shape. A few vague markings are seen during the brief look, but what they are is not immediately apparent.

But the real excitement of the mission is about the close-up look at the big four "planets" discovered by Galileo, which, unlike diminutive Amalthea, are true worlds. Our narrow-angle camera has been showing more and more detail on their surfaces, and large-scale features have already appeared on the viewing screens. But the scientists, though tantalized by the remarkable images, sensibly refuse to speculate. "Why speculate," says one noted sage, "when in a few hours we'll know?"

The Galilean worlds are a puzzle. The innermost two, Io and Europa, are the densest and heaviest, indicating that they are composed chiefly of rock. But they are also among the lightest-colored objects in the solar system, reflecting over 60% of the light that falls on them. This may mean that their surface layer is of ice.

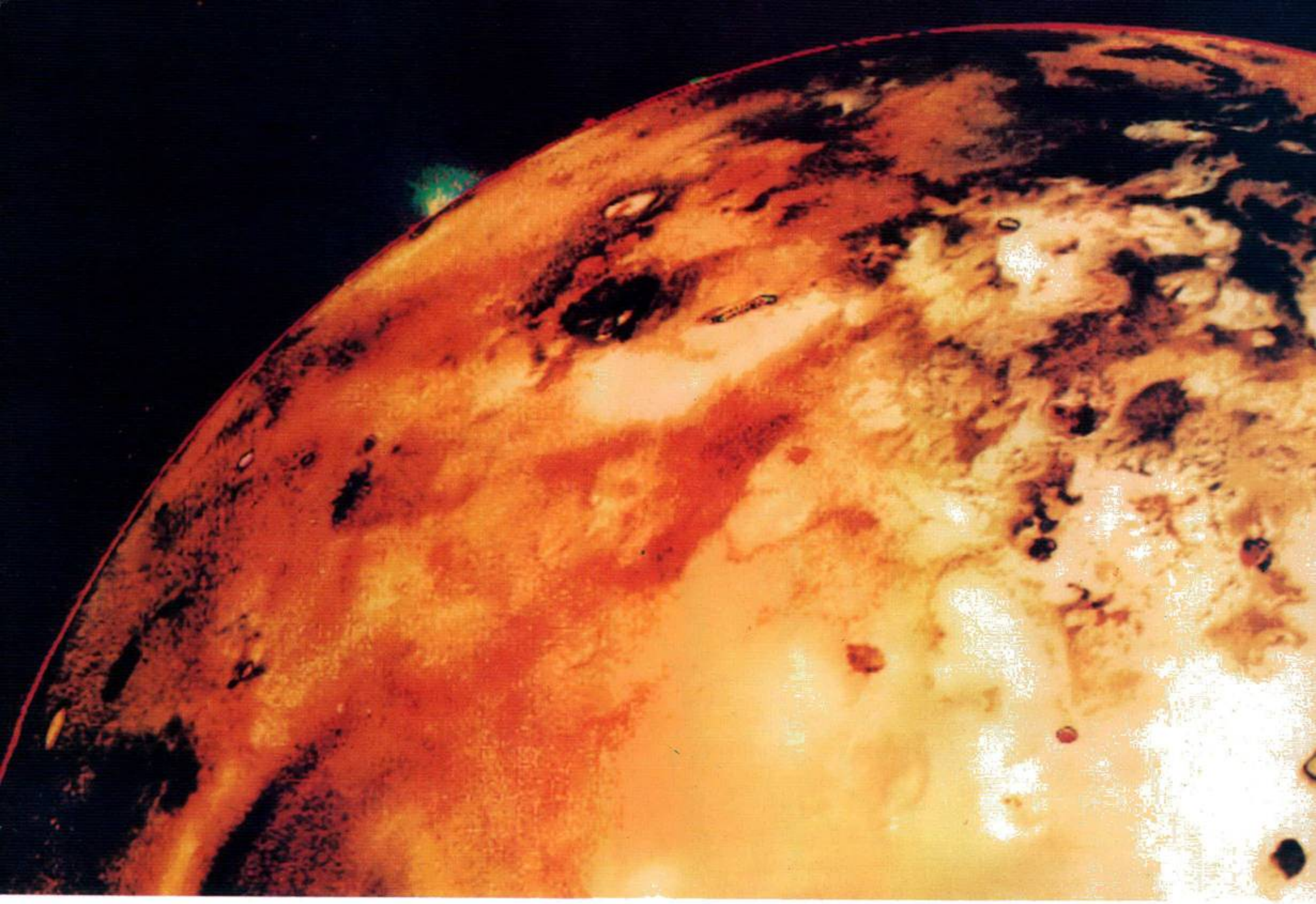
The outer two, both larger than Io and Europa, seem to be altogether different. Their density is much less than that of Io and Europa, showing that they must be composed chiefly of water ice, having perhaps a small rocky core. Yet for all that ice, Ganymede and Callisto are much less reflective than the inner two. Maybe the ice surfaces are very dirty. Anyway, we'll know before long, as they pass below our lenses in a few hours.

The first to be examined is the strangest of them all, orange-red Io. Just three hours after closest approach to Jupiter, the spacecraft, which has swung below the equatorial plane of Jupiter, rushes almost directly "under" the south pole of Io, passing through the peculiar flux tube at the same time. Fortunately, some of the most intriguing features are well-placed for the high-resolution cameras. The results are nearly unbelievable, for Io turns out to be nothing at all like what we thought (see page 10).

Then, as seen from the spacecraft, Earth is occulted by Jupiter. Communication with home is cut off, and all our data must be recorded for later playback. After about an hour, we see the Sun eclipsed by the giant planet, which now appears as a dark disk surrounded by a bright ring, sunlight refracted around Jupiter by its atmosphere. Earth and Sun occultation each last about two hours.

Rising once again above Jupiter's equatorial plane about six hours after closest approach, we come as close to Europa as we will get on this mission — 455,000 miles. Still too distant to observe its surface features in great detail, Europa will be examined much more closely in four months by Voyager 2.

14 hours past closest approach, we swoop within 71,500 miles of Ganymede, the third of the Galilean worlds (see page 14). More surprises greet us, as each of these strange new planets reveals characteristics and surface geology never before seen anywhere in the solar system. The simple truth is: each of these worlds is unique.



This photograph of a plume-like structure rising some 60 miles above the surface of Io shows a cloud of dust produced by an active volcanic eruption. This is one of four eruptions so far discovered on Io, making Io the most volcanically active body in the known solar system. Scientists believe closer analysis will reveal more features with activity. Io is nearly airless, so dust particles follow ballistic trajectories. The volcano is surrounded by a large cloud of gases not visible in the photograph. Infrared measurements show the regions around the volcanos are several hundred degrees warmer than the surrounding terrain. Scientists suspect Io may be undergoing continuous volcanism, making its surface even younger than previously thought. JPL/NASA photograph.

We now enter the first of the *post encounter* phases as Jupiter is left farther and farther behind us. Yet we still have to make our closest approach to Callisto, outermost of the four Galilean planets (see page 18). Passing 77,000 miles over its north pole, just 29 hours after closest approach to Jupiter, Voyager's cameras take more than 100 pictures detailing its visible surface.

Amazing as our expedition has been so far, we haven't even concluded the Jupiter part of our two-fold mission. The two post encounter phases will continue for 35 days as the spacecraft moves out of the jovian system and once more into deep space.

During the months ahead scientists back on Earth will study and analyze the immense quantity of data recorded, while all of us marvel at the great planet now revealed. Undoubtedly more discoveries will be made — and remember just four months behind us is Voyager 2.

Voyager 1 has used the mighty gravity of Jupiter during the flyby to accelerate and redirect itself toward our next target: Saturn. As observations of Jupiter and its unique family wind down, we prepare to enter the long *Jupiter-Saturn cruise* phase of our expedition. This phase will last fully 16 months before we draw near enough to begin another observatory phase (in August of 1980), this time of the next planet out in the endlessly fascinating solar system, beautiful, ringed Saturn.

> "Voyager is not an entity unto itself. Voyager is an extension of ourselves, literally and figuratively. It runs in conjunction with people on Earth. Computers and their intelligence and your eye-brain combinations complete the circuit. I think it is useful to use this occasion to reflect on this process. We are indeed evolving as a species in an unusual way and none of us knows where this will lead. But certainly what is happening now, when our ganglions are tied 500 million miles away to robot eyes and other sensors, and we can sit here and contemplate that and let our intellectual power operate on those signals, this is a phase of human development which will never again have to be repeated. For better or for worse, man the tool maker is evolving to a concept that none of us have fully contemplated."
>
> — *Dr. Bruce Murray, Director of the J.P.L.*

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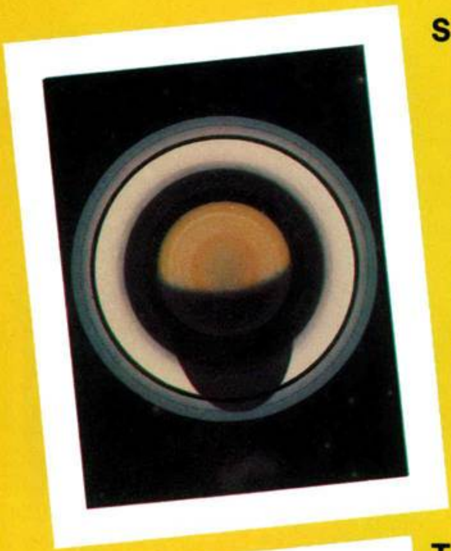

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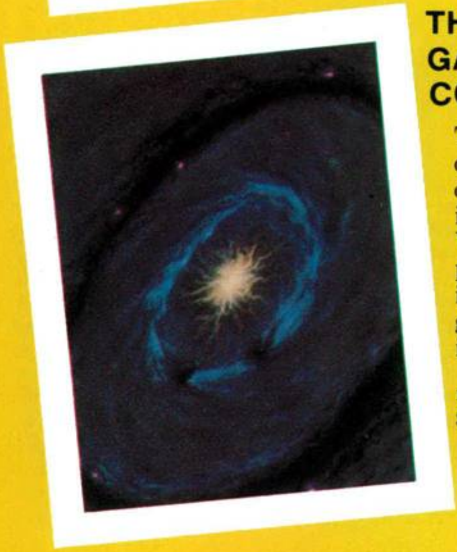

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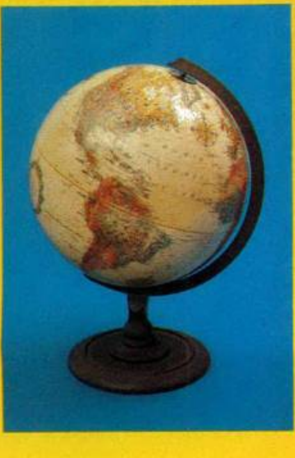

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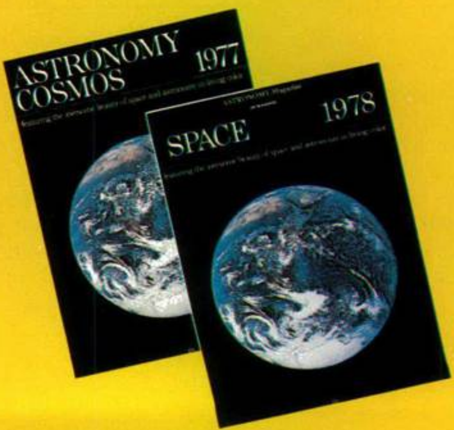

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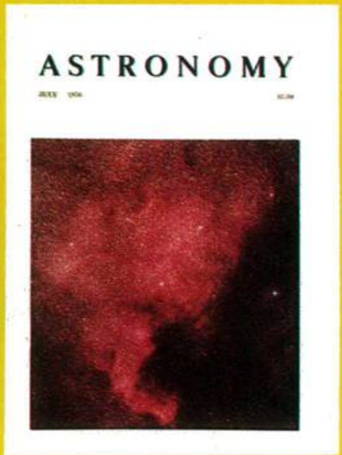

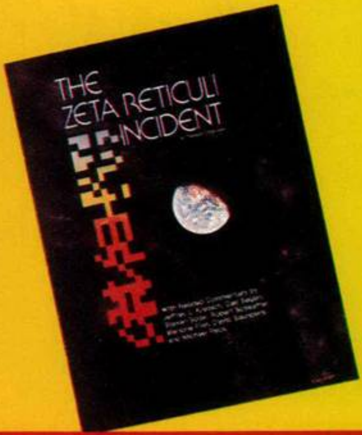

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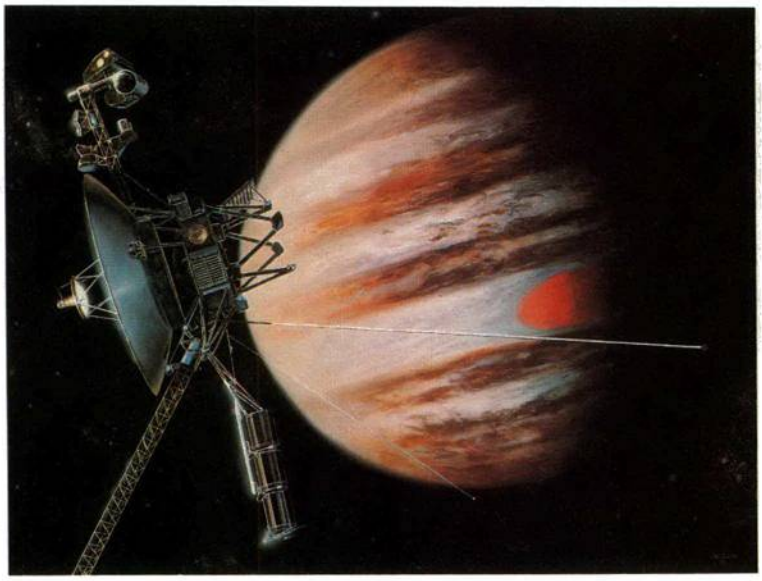

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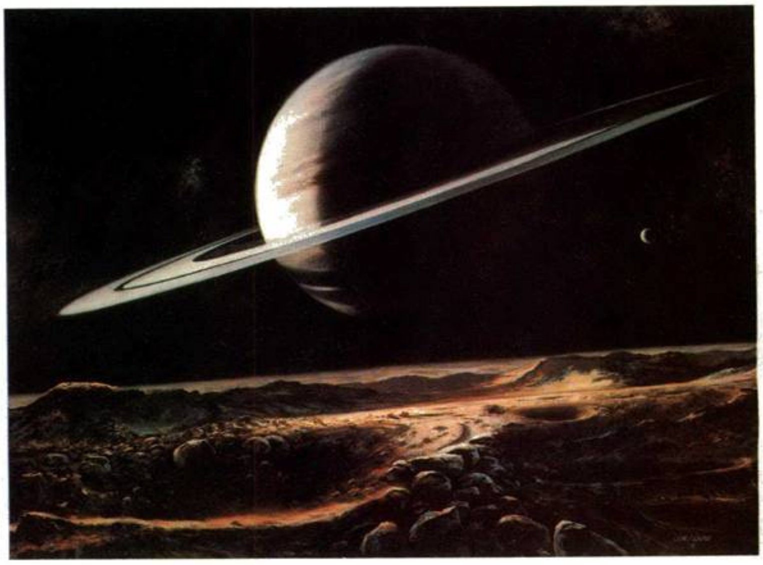

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ASTRO-NEWS

Latest News From the World of Astronomy

Saturn May Have Another "Ring"

The famous rings of Saturn have long been familiar to everyone, not just amateur and professional astronomers. Now evidence seems to be accumulating that there may be another "ring" of sorts around the giant planet — outside the familiar rings and composed of a number of fairly large hunks of matter, including perhaps some small asteroid-size bodies.

The spectacle of Saturn's rings, so popular with space artists, is heightened by the fact that the plane of the rings is inclined to the orbit of Earth. This means that we usually see the rings clearly displayed at an angle, rather than always edge-on. But twice during Saturn's orbital period of 29½ years, Earth passes through the plane of the rings and they become extremely difficult to observe. 1979-80 is such a passage "year."

Observations of Saturn during times of passage through the ring plane can yield much information. During the last passage in 1966, investigators refined estimates of the thickness of the rings to a figure of 1.3 ± 0.3 km — less than one mile.

A less certain result of observations in 1966 was the discovery of a tenth satellite of Saturn. A. Dollfus of the Pic-du-Midi Observatory in France announced the detection of a new satellite in an orbit very close to the rings. He proposed the name Janus for this tenth satellite. But the existence of a satellite is regarded as definite only when a precise orbit has been calculated and the satellite has been subsequently observed. Neither of these two criteria have yet been met in the case of Janus, for a number of different possible orbits have been suggested.

Even less certain is the 1977 identification of an eleventh satellite announced by John W. Fountain and Stephen M. Larson of the Lunar and Planetary Laboratory at the University of Arizona. Fountain and Larson studied a number of plates taken during the 1966 passage, and found what they called "marginal" images of unidentified satellites. Their calculations indicated that the images could be accounted for by postulating the existence of two new satellites, one of which closely corresponds to Dollfus's Janus.

Writing in the August 26, 1977 issue of **Science**, and again more recently in the October 1978 issue of **Icarus**, the two astronomers concluded that Saturn has at least eleven satellites, and that the two new close satellites (with orbital radii of about 94,000 miles and 99,000 miles) could be only two of a number of small satellites constituting a faint outermost ring system.

This is not the first time that additional satellites have been found for Saturn. In 1905 William Pickering, who had discovered Phoebe (the ninth satellite) in 1898, announced the discovery of a tenth, which he dubbed Themis. The existence of Themis, however, was never confirmed, and a recent re-examination of the original plates has cast doubt on Pickering's discovery.

K. Aksnes and F.A. Franklin of the Harvard-Smithsonian Center for Astrophysics, the same scientists who concluded there is no evidence for the existence of Pickering's Themis, also examined the evidence for Janus and an eleventh satellite, and found it inconclusive. Writing in the October 1978 issue of **Icarus**, the two authors concluded that while the efforts of Dollfus, Fountain, and Larson seem to establish that the region just outside ring A may contain several small bodies in nearby orbits as a sort of thin, large-particle "ring" near the Roche limit, present evidence makes unambiguous orbital calculations impossible.

The ring passage later this year will be closely watched by observers for additional evidence, and it may be possible for the Voyager spacecraft to return better images than the Earth-based photographs during its Saturn encounter shortly afterwards.

Violent Meteor Impacts May Have Caused Maria on Moon

A new theory to explain the creation of both the Moon's magnetism and its circular maria (the craterlike seas), has been offered by a Pennsylvania State University scientist.

Dr. Frank Dachille, a professor of geochemistry, suggests that these phenomena were caused simultaneously by the incredibly forceful electric and magnetic fields generated by the impact of very large meteorites or asteroids striking the Moon.

"Our experiments have shown," says Dachille, "that when projectiles speeding along at 20,000 feet per second strike a target, very definite electromagnetic fields are produced. When calculations are extended to meteoritic projectiles, surprisingly intense magnetic and electric fields are to be expected — fields far more powerful than those of lightning or the strongest electromagnets known. Such fields, we believe, could be induced only by the forced separation of electrons from the atoms of the colliding objects."

So powerful is the impact, he continues, that at the instant of collision, electrons are torn free of their atoms. Propelled by their massive momentum, the now positively charged atoms (or ions) tend to continue moving in the same direction the larger object had been traveling. At the same time, the very much lighter, negatively-charged electrons are deflected more or less radially from this line. The mix — a so-called "plasma" — of the powerful positive

Maria *continued on page 59*

Unique Observatory Design Studied For Proposed Australian Facility

A new optical telescope, which combines three major technological advances, has been proposed as a national facility for Australian universities.

The telescope, designed by a team of astronomers and engineers from the Australian National University's Mount Stromlo and Siding Spring Observatories, uses some recent innovations in telescope design and technology which have not been previously combined in one instrument. These include an unusually thin large mirror, a vertical/horizontal altazimuth mounting, and a rotating building housing the telescope.

The acting director of the observatories, Dr. Don Mathewson, said the proposed 120-inch (3 meter) telescope would cost one quarter as much to build as a conventional telescope of the same size. It could operate 24 hours a day, and would be used mainly as a national teaching instrument by Australia's universities. Other groups would also be able to use it for research projects.

Thin mirrors of high optical quality have been developed recently in England. They are much lighter than conventional mirrors and allow considerable savings in construction. The Australian telescope would have a mirror just 6 inches thick and would weigh only a few tons. A similar thin mirror is presently in use with the British infrared telescope located in Hawaii.

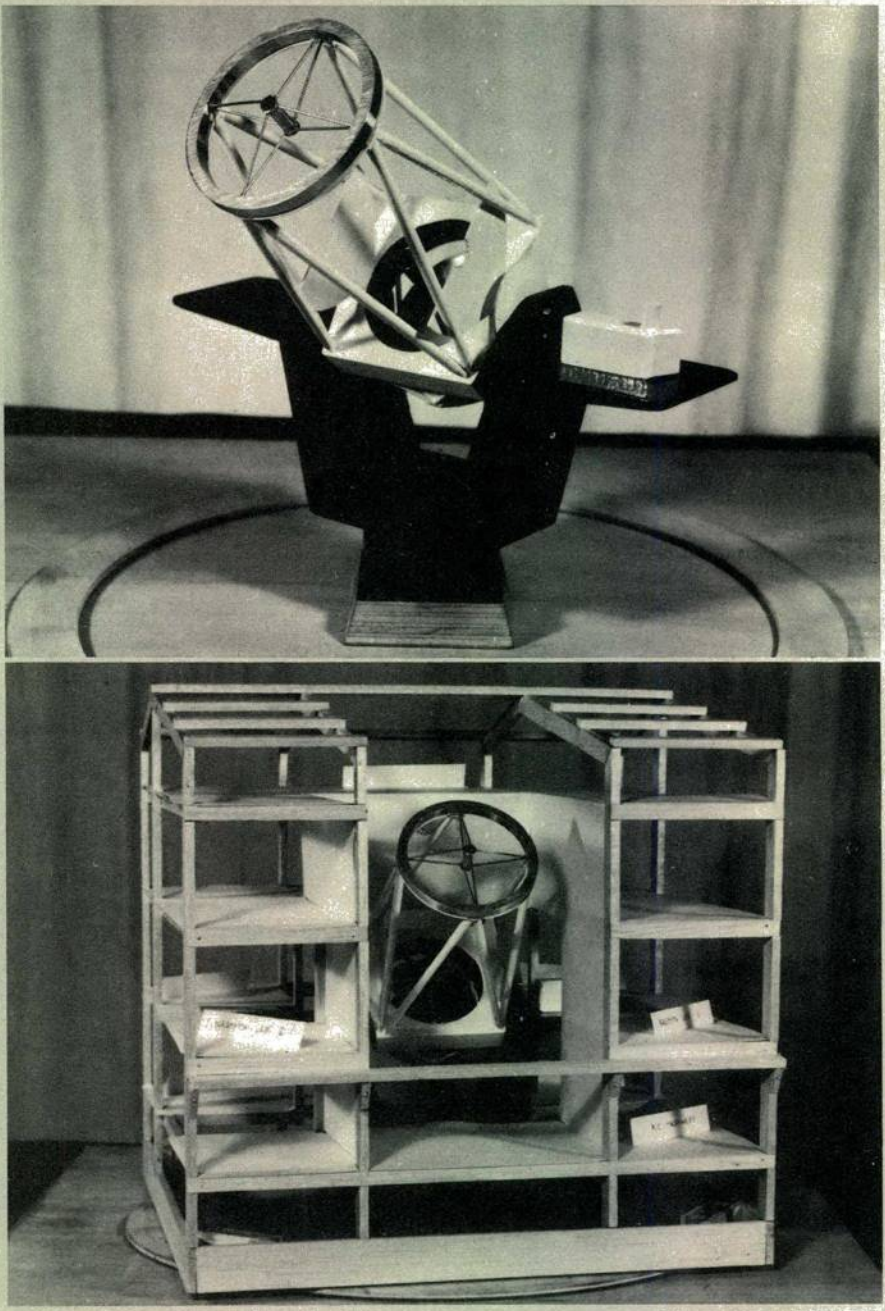
The unique altazimuth mounting has been developed extensively in the Soviet Union and is now in use on the Soviet 236-inch (6 meter) telescope and with the United States' Multiple Mirror Telescope at Mount Hopkins, Arizona. The new mount is much simpler as it allows movement only in a vertical and horizontal plane, unlike the equatorial mounts of conventional telescopes. This eliminates the need for a conventional telescope dome, cutting costs and allowing easier access to the telescope as well as simplifying the engineering design. Heavy equipment can be set up on the two stationary platforms to either side of the telescope, allowing quick instrument changes and much greater flexibility in programming observations.

The proposed telescope could make infrared observations during daylight and change to optical programs at night.

The unique design has attracted interest in other parts of the world. A United States universities group — the Associated Universities for Research in Astronomy (AURA) — would like to build a similar telescope and has suggested joining the Australian group in design work. AURA is currently responsible for the operation of the Cerro Tololo Inter-American Observatory in Chile, a facility of the Kitt Peak National Observatory. Italian astronomers have also expressed interest in joining the project.

Other groups have made offers of assistance. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, has sent the Austra-

Telescope *continued on page 59*



The top photograph shows a working model of the proposed Australian 120-inch telescope. The unique altazimuth mounting was originally developed in the Soviet Union. The primary mirror will be only six inches thick, unusually thin for a mirror of that size. Seen below is the proposed telescope within its rotating building. This design allows instruments to be placed on the fixed platforms on either side of the telescope.

Is the Sun a Double Star?

Most of the stars in the Sun's neighborhood are members of double or multiple systems, in some cases possessing unseen companions whose presence is known only by perturbations in the visible star's path. Both the Alpha Centauri and Sirius systems are examples. Astronomers have long wondered if the Sun is indeed unusual in being a lone star with no companions other than its system of planets and smaller bodies. It now appears that this is in fact the case.

In 1977 E.R. Harrison of the University of Massachusetts proposed that the Sun might have a companion. His suggestion was prompted by consideration of an unusual anomaly in observations of pulsar periods.

Pulsars, which are thought to be rapidly rotating neutron stars, emit signals at very precise intervals. But because of the loss of energy by radiation, each pulsar's period has been observed to increase slowly as its spin rate declines. The rate of this decline can be very exactly observed.

Harrison found that of 62 pulsars whose rate of decline is known, 23 lie within a region of sky 40° by 60° in extent. Of these 23, five have strangely small rates of decline. Harrison calculated that the random possibility of five pulsars clustering in this way is one in a hundred. Furthermore, even if the clustering is explained by chance, this would leave the origin of the small rates of decline unknown.

Harrison suggested that the small rates of decline of period could be explained by an acceleration of the solar system toward the pulsars in question. A good mechanism for such an acceleration of the solar system's center of gravity would be a companion body to the Sun. This companion could be either in a closed (permanent) orbit, making the Sun a member of a true binary system, or a body passing by on an open trajectory close enough to perturb the Sun's motion by the right amount.

Harrison's proposal was controversial because, in the first place, a solar companion would naturally exhibit a large proper motion against the background of more distant stars. But surveys of proper motions have been carried out for all stars (to 14th magnitude) with movements greater than a half second of arc per year and would certainly have revealed such an object. Therefore, in order to escape detection, a solar companion would have to be exceedingly faint. Harrison suggested the requirements could be filled by a crystallized white dwarf of very low luminosity, a very faint red dwarf, or a black dwarf (a "star" too lacking in mass to ignite thermonuclear reactions). A black hole or a neutron star could also fill the bill, but both these objects are born in massive stellar explosions which would have disrupted a weakly-bound solar binary system. If the companion were a black hole or a neutron star, it must be in an open, unbound orbit only temporarily passing the Sun and, therefore, not a permanent companion.

More recently, however, J. Kirk of the Max Planck Institute for Physics and Astrophysics in Munich reported calculations which exclude the existence of a solar companion in a bound orbit. Writing in **Nature**, Kirk pointed out that if the center of gravity of the solar system were truly being accelerated, as Harrison had proposed to account for the observed pulsar anomaly, the orbits of "new" comets would be affected in observable ways. Such effects are not in fact observed, and therefore the Sun can't have a permanently bound companion.

In the case of an unbound, passing encounter, however, the possibility that the Sun has a temporary companion cannot be excluded. Such a companion, according to Kirk's calculations, must have a velocity of at least 20 kilometers per second, and the period of time during its passage when it could affect the solar system in any detectable way would have to be less than 2000 years.

It, therefore, seems the Sun is indeed a galactic loner, with only its family of planets and various smaller bodies to keep it company on its journey through space.

Chiron's Orbit Found Unstable

In October of 1977, Charles T. Kowal discovered a unique object in orbit around the Sun farther out than Saturn. Initially designated 1977 UB, the object was named Chiron by its discoverer. It was the first such object found, and scientists seemed uncertain whether to regard it as a minor planet (asteroid) or a comet, though it was finally given the designation Minor Planet 2060. Better observations revealed that its perihelion lies within Saturn's orbit, while its aphelion is not much less than the distance of Uranus. It quickly became obvious that close approaches to both planets could occur.

Now Shio Oikawa and Edgar Everhart of the University of Denver have performed calculations which demonstrate that Chiron is now in the control of Saturn, that it has an unstable orbital pattern at present, and therefore that its distant past and future orbits cannot be known accurately.

Reporting in the **Astronomical Journal**, the researchers found that while the orbital history of Chiron can't be exactly determined, certain statistical probabilities could be calculated. Analyzing 60 cases, involving about 230,000 revolutions, Oikawa and Everhart found that there is one chance in eight that Chiron will be thrown out of the solar system altogether by a close encounter with Saturn. If Chiron is indeed ejected from the solar system, there is a fifty-fifty chance of the ejection occurring within the next three million years. On the other hand, there are seven chances in eight that Chiron's orbit will be perturbed inward until it can be strongly affected by Jupiter. The average time in which this could take place is a little over 100,000 years.

It is clear that Chiron is in a chaotic orbit, one which never reaches a stable form — although an object in a chaotic orbit may spend as much as a million years or more in a quasi-stable pattern. Chaotic orbits eventually evolve into an open hyperbola (which means the object escapes from the system), but this may take a very long time. So even if Chiron's orbit evolves inward — the most likely case — encounters with Jupiter (instead of Saturn) will still eventually lead to its expulsion from the solar system.

Oikawa and Everhart note that any object having a chaotic orbit could not have been a member of the solar system from the beginning. In this respect, the problem of Chiron is similar to that of the comets. Chiron could be a wandering interstellar piece of debris which was captured by Saturn at some point in the past, or perhaps originally by Jupiter with a later outward evolution leading to its present orbit.

At present, Chiron is the only minor member of the solar system known to be interacting primarily with Saturn.

Very Long Baseline Interferometry Becomes Powerful Astronomical Tool

Very Long Baseline Interferometry (VLBI) is a relatively new technique in which large radio antennas at widely separated points on Earth measure the arrival times of quasar signals. Quasars, the most powerful radio emitters known, are believed to be so far away that some signals reaching Earth today started their journey when dinosaurs first roamed the world, and in a few cases, the signals left their source before the Earth was formed. By the time those signals reach Earth, they are only about as strong as the beam from a small pocket flashlight as seen from Pluto's distance.

While ordinary celestial objects appear to move relative to each other, quasars are so far away that they have no apparent relative motion among them and are therefore ideal reference points. VLBI measurements allow experimenters to do such disparate tasks as spacecraft navigation, measuring the distance between points on Earth, synchronizing atomic clocks, and detecting minute movements in Earth's crust.

A scientific team based at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California has been improving the technique. Members of the team include J. Brooks Thomas, John Fanselow, George Purcell, Eric Cohen, Lyle Skjerve, and David Rogstad. The JPL scientists have measured distances between NASA's Deep Space Network stations at Goldstone (California), Madrid (Spain), and Canberra (Australia) with an accuracy of 10 to 30 inches. That's the same as measuring the distance between two objects one mile apart to an accuracy of the thickness of a human hair.

Synchronizing clocks is necessary for navigating spacecraft through the solar system. According to Dr. Thomas of the JPL team, by July 1979, the VLBI technique will allow Deep Space Network clocks to be synchronized to within ten billionths of a second. Future systems are expected to be accurate within a billionth of a second.

The ability to measure Earth's continental drift is being improved using VLBI and quasars. Twice each day, the ground moves up and down as much as 15 inches in a tidal response to the Sun and Moon. The continents also move relative to each other at about the same rate as fingernails grow. That movement, and the related local warping that occurs as large crustal plates collide, are involved in the generation of earthquakes. (The JPL scientists estimate that within the next ten years they will be able to detect changes as small as one to two inches in the relative locations of any two points on the Earth's surface.)

By using quasars as navigation beacons for spacecraft, engineers expect to deliver payloads to targets as distant as the planet Jupiter with an accuracy of 25 miles. The first major tests of that capability are the Jupiter encounters of Voyager 1 and 2 this year. If judged successful, the quasars will help guide the *Galileo* spacecraft, scheduled for launch in 1982, to Jupiter.

Galileo will send an observing station into orbit around Jupiter, passing close to several of the giant planet's large satellites. The mission will require high-precision navigation, particularly near Mars, where the spacecraft will get a gravity assist. Accurate navigation during that gravity assist is essential if the spacecraft is to use the least amount of fuel possible to arrive on target at Jupiter in 1985.

Gigantic Solar Upwellings May Be Due to Circulation Pattern

A Hale Observatories astronomer has discovered evidence for gigantic upwellings on the Sun, features which may tell us something about the origin of sunspots and solar flares. The upwellings, which happen occasionally, average around 300,000 kilometers in diameter, or more than 20 times the diameter of Earth.

The findings by Dr. Robert Howard were reported in the **Astrophysical Journal** and represent the first time that such huge circulation patterns have been detected on the Sun. Until now, it was believed that the largest "velocity features" on the Sun's surface were supergranular cells, circular areas about 30,000 km in diameter in which hot gas wells up in the center and sinks at the edges, rather like the seething motion of water in a pan as it nears the boiling point. The Sun is also mottled by even smaller granules about 1,000 km in diameter.

The huge upwellings were found to concentrate near the Sun's equator and to be about three to four times longer than they were wide, according to Dr. Howard.

"I would judge that these features are an important part of the dynamics of the solar interior which lead to magnetically active regions on the sun," said Howard. "Such active regions give rise to sunspots and solar flares, about which we know so little."

"At present, no one knows why or where or when sunspots will form. We can only predict them statistically, for example, in terms of the 11-year cycle of solar activity. The discovery of these large-scale features, however, offers a clue to the origin of active regions. There is a strong possibility that we may be able to gather enough data to predict at least where complexes of solar activity that give rise to sunspots and flares will happen."

In one case, according to Dr. Howard, such a large-scale velocity feature lasted for 16 rotations of the Sun, and pre-dated the emergence of a region of solar activity by about two revolutions. (The Sun rotates once every 25 days at its equator.)

The large magnetic fields associated with sunspots often give rise to solar flares, immense eruptions on the Sun's surface that unleash the energy equivalent of a million hydrogen bombs. These eruptions disrupt radio communications worldwide and produce spectacular aurorae, as the charged particles from them reach Earth.

Dr. Howard obtained the evidence for the large upwellings by analyzing data from daily scans of the Sun's surface taken since 1967, using the Mount Wilson 150-foot Tower Telescope. The data consist of scans of the surface at a wavelength of 5250.2 Angstroms, which is one of the wavelengths at which neutral iron on the Sun's surface absorbs light.

Tiny shifts in wavelength of these emissions at various points on the sun are due to the Doppler effect produced by gas moving either upward toward the Earth, or downward away from it. Dr. Howard analyzed Doppler shift data produced by the daily scans. He then generated maps of solar circulation patterns, which revealed the presence of the upwellings.

Galaxies Found Near Local Group

The "Local Group" is the cluster of galaxies to which our own belongs. It is a sparse cluster as galactic clusters go: in comparison to the Virgo cluster, for example, whose members are counted in hundreds, our own cluster is numbered in tens. The Local Group also seems to be relatively isolated from other clusters of galaxies. Vast spaces separate the members of the Local Group from its nearest neighbors. But now the identification of a nearby galaxy which is not a member of the Local Group has raised the possibility that there may be another group of galaxies located between our own and the closest previously known cluster.

While the Local Group has relatively few members, astronomers are continually identifying new ones. These are all tiny, low-density dwarf galaxies whose presence is barely noticeable behind the stars of our own galaxy. Most recently, Charles Kowal, K.Y. Lo, and Wallace L.W. Sargent of the Hale Observatories have announced the discovery of five new nearby dwarf galaxies, three of which seem to be members of the Local Group. One of these has now been confirmed as a Local Group member (by measurement of its velocity relative to us) by T.X. Thuan and G. Martin of the University of Virginia. All five galaxies are located between 20 and 35 degrees north declination, 0 and 1 hour right ascension, and range in brightness from 18th to 20th magnitude.

Another nearby galaxy which does not seem to belong to the Local Group has been discovered by Riccardo Giovanelli of the National Astronomy and Ionosphere Center in Arecibo, Puerto Rico. Located in Orion, the new galaxy was discovered accidentally in the process of a radio telescope survey at the 21 cm line of neutral hydrogen. It has been identified optically on previous photographs of the region, and a new plate taken with the 156-inch telescope at the Cerro Tololo Inter-American Observatory shows it clearly.

Measurement of its velocity indicates that although it's nearby, the new galaxy is not a member of the Local Group. Reporting the discovery in the **Astrophysical Journal Letters** (February 1), Giovanelli suggests that the new galaxy may be a member of an unidentified nearby group of galaxies closer to the Local Group than any other galactic cluster.

The new galaxy is centered at R.A. $05^h42^m22^s$, Dec. +5°02′30″, on the edge of the so-called "zone of avoidance" in the plane of our own galaxy where the view is obscured by foreground dust. If a nearby cluster of galaxies is located in the zone of avoidance, its members would be very difficult to detect.

Maria *continued from page 55*

and negative electric currents thus created produces immense electric and magnetic fields.

The extent of these fields will vary with the size and speed of the meteorite. They may extend as little as a mile, or as much as 1,000 miles or more.

"We estimate that a colliding mass, dense enough and moving fast enough to form the equivalent of a lunar mare (at least 300 to 400 miles in diameter), would do two things to a body such as the moon," claims Dachille. "The first is that the electric field thus produced would cause the breakdown, into an almost fluidized powder, of all materials within several hundred miles of the point of impact. The second is that the incredible intensity of the magnetic field would alter the direction of magnetic polarity of all magnetizable or ferro-magnetic constituents of the moon."

The first occurrence, according to Dachille, could explain the seabed-like appearance of the circular lunar maria, for if the lunar crust had been partially fluidized at the instant of impact, the surface materials would later have flowed back into the crater, forming an oceanlike floor.

At the same time, Dachille theorizes, the magnetization change would have generated a magnetic field on a body such as the Moon, which previously had no such field. "One of the puzzling mysteries about the Moon," he explains, "is the finding of a sparse magnetic field, which seems to be concentrated around some of the Moon's larger craters. Given what we know and can speculate about the Moon's makeup and origins, it shouldn't have any magnetic field. Other theories have been offered to explain this. We think ours is the simplest and most plausible. The collision process, involving large projectiles, is known to have been very prevalent in the planetary system. An unavoidable consequence of such collisions would be the creation of intense magnetic fields."

Dachille simulated mathematically the conditions which would result from massive planetary impacts. He found that a projectile traveling as slowly as four or five miles per second, would create electric and magnetic pulses. Meteorites travel between 3 and 40 miles per second, with the majority colliding at 18 to 24 miles per second.

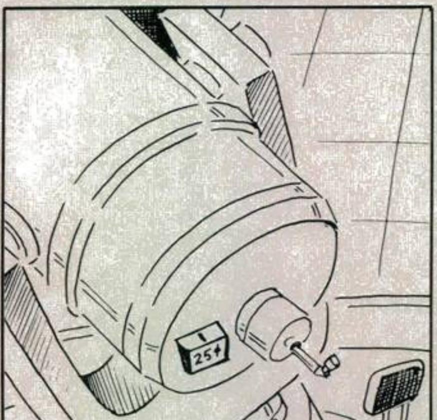
"A meteorite at least 100 feet in diameter, moving 18 to 24 miles per second," he conjectures, "would generate sufficient energy upon impact to strip six or seven electrons from each of the countless billions of colliding atoms. When these electrons are separated in a plasma from positive ions by inertia, powerful electric and magnetic fields are formed."

If such a collision were to involve a comet nucleus and gases far from the Sun, he further speculates, similar electric and magnetic currents could be the source of the comet's coma or visible halo. For only a force of astronomical intensity, Dachille argues — produced by the inertial separation of ions from electrons — can account for the fact that comets beyond the orbit of Saturn are visible on Earth.

Telescope *continued from page 56*

lian group complete plans of its own rotating building. The Kitt Peak National Observatory has offered to help with the mirror. And the Northern Hemisphere Observatory has offered assistance with computer studies for the altazimuth mount.

Planning for the new telescope began in early 1978, and since then, meetings have been held between astronomers from Australian universities, the Australian Commonwealth Scientific and Industrial Research Organization, and the Anglo-Australian Observatory.



BRIEFS

- The familiar Crab Nebula is known to have been produced by a supernova observed nearly a thousand years ago in China. Now, according to a recent report in **Nature**, it seems that the star which gave rise to the Crab Nebula may have been a helium star in a close binary system already containing a neutron star. The explosion observed by the Chinese astronomers would have been caused by the neutron star spiraling into the helium star and destroying it.

According to R. K. Kochhar of the University of Gottingen in Germany, the presently observed neutron star in the Crab, PSR 0532, may be the disrupting star, accelerated to its high spin rate by the explosive encounter. Rather than being a young pulsar, it would instead be a "rejuvenated" old one whose high spin rate gives it an appearance of youth.

- A University of Texas astronomer has discovered what he believes are two new comets traveling in close parallel orbits through the solar system. Such double comets are a rare occurrence, according to Dr. J. Derral Mulholland who made the accidental discovery. It may be that the two objects he has observed were originally a single comet which broke apart only recently when it passed close to Jupiter and came within the massive planet's strong gravitational field.

If this is true, it means there will be fresh surfaces on the two bodies emitting spectra which can be analyzed to determine the comets' chemical composition.

- NASA's Nimbus 7 satellite, launched in 1978, may be instrumental in providing new and more accurate information about pollution of the Great Lakes. The satellite carries 7 sophisticated sensing devices designed to measure factors ranging from stratospheric aerosols and ozone to polar sea-ice extent.

"George, I hate to tell you this...."

- The Space Shuttle's solid fuel rocket motor, largest of its type ever built for manned space flight, has successfully completed a series of four developmental static firings. The qualification firing tests, which have recently begun, will qualify the motor for use in the first manned flight of the Space Shuttle and will demonstrate the production, assembly, and firing cycle needed to support a full schedule of Shuttle flights.

Two of the motors will be used on each Shuttle. During a launch, the motors operate for about two minutes and separate on burnout at an altitude of about 27 miles. A parachute recovery system then lowers them into the ocean where they will be recovered and used again.

- Recently, three fireball meteors were detected by infrared sensors aboard Earth-circling satellites. According to R.D. Rawcliffe, reporting in the **Astrophysical Journal** (February 15), one of the meteors was observed simultaneously by two satellites, enabling triangulation measurements. These measurements indicated the fireball encountered Earth with a relative velocity of about 12 miles per second and weighed about 8½ tons.

- NASA and the European Space Agency (ESA) have signed memoranda of understanding related to the use of data transmitted by the United States' Landsat and Nimbus 7 satellites. The memoranda concern the acquisition of data by European ground stations, pre-processing and distribution of data from the Landsat series of satellites, and several ESA-coordinated investigations involving data received in Europe from Nimbus 7.

- The European Space Agency is considering the launch of an astrometric satellite in 1984. An astrometric satellite would be able to make measurements of stellar positions and parallaxes far more precisely than Earth-based telescopes. To be called *Hipparchos* after the ancient Greek astronomer who prepared the first star catalog, the satellite from its station in a geosynchronous (24 hour) orbit, would measure the position, proper motion, and parallax of over 100,000 stars. Accurate distances for stars out to a distance of 250 light-years could be quickly obtained, and such data would greatly improve the whole astronomical distance scale.

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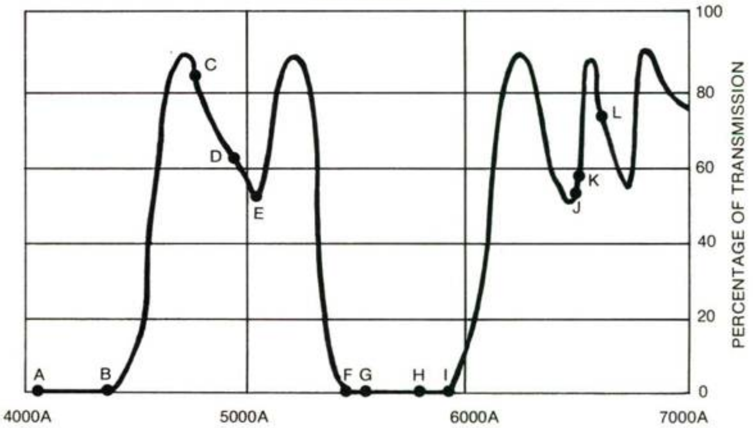

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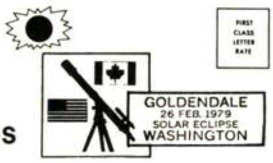

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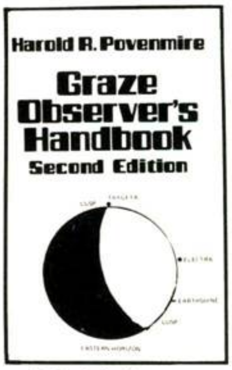

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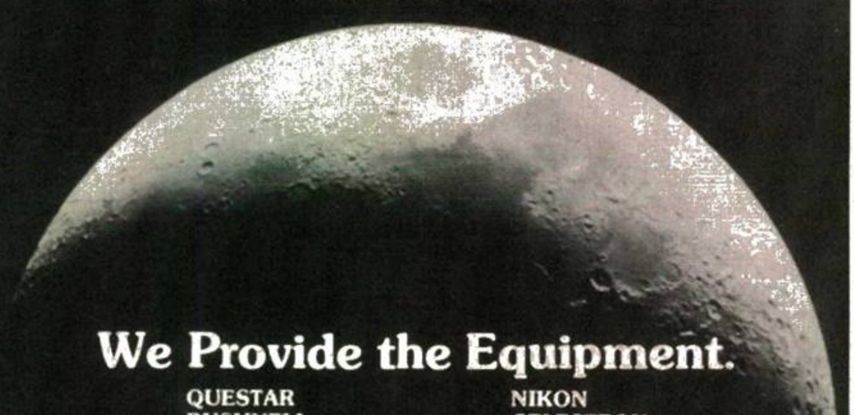

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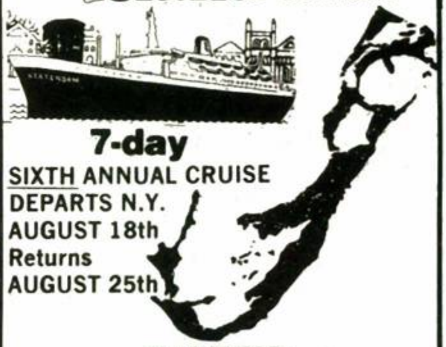

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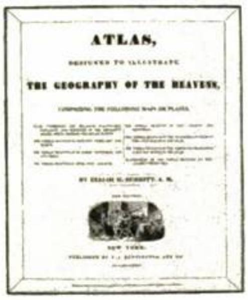

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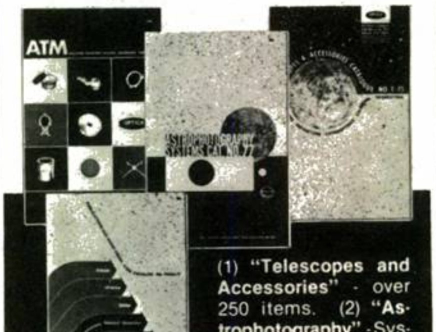

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ANNOUNCEMENT — The Astronomical Society of the Pacific is compiling regional astronomy directories, listing amateur clubs, observatories, planetariums, courses, and stores for the U.S. and Canada. For a free listing questionnaire, send a SASE to Directories, A.S.P., 1290 24th Ave., San Francisco, CA 94122.

ANNOUNCEMENT — Interested space enthusiasts invited to attend recently formed L-5 Society of Detroit-metro area. For details, write Dr. Brian L. Kerman, 27031 Dequindre, Madison Heights, MI 48071. Phone (313) 545-4888.

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ANNOUNCEMENT — Fort Wayne Astronomical Society meets on 3rd Tuesday of each month at the Fox Island meeting room at 7:30 p.m. General public is invited to attend. For information, contact Ron Mader, P.O. Box 6004, Fort Wayne, IN 46896. Phone (219) 447-4196.

ANNOUNCEMENT — Northwest Astronomy Net meets each Sunday night at 10 p.m. Pacific Standard or Daylight time on 3.925 megahertz. It's amateur radio operators who enjoy astronomy, radio astronomy, telescope making and related sciences. Check-ins from anywhere are welcome. Contact Forrest W. Smith (WB7AEA), P.O. Box 531, Gearhart, OR 97138.

ANNOUNCEMENT — Eclipse of Sun; February 1980; Africa, Grecian antiquities, Egyptian Pyramids. Dialogue welcome. Interesting, talented people exchange dreams, questions, ideas, plans. Trip of lifetime; singles welcome. Contact Dr. Suzzette A. Rochaette, 725 Prospect Ave., 3-C, Cleveland, OH 44115. Phone (216) 696-6894.

ANNOUNCEMENT — General Assembly '79; Royal Astronomical Society of Canada, at London, Ontario; May 18-21. Displays, papers, prizes, trips, observing. Special guest: Dr. Gerard K. O'Neill. Details: London RASC, P.O. Box 842, Station B, London, Ontario, CANADA N6A 4A3.

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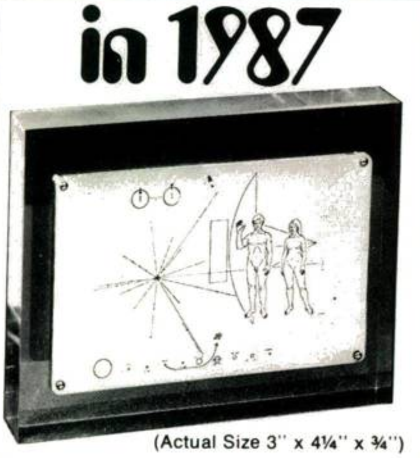

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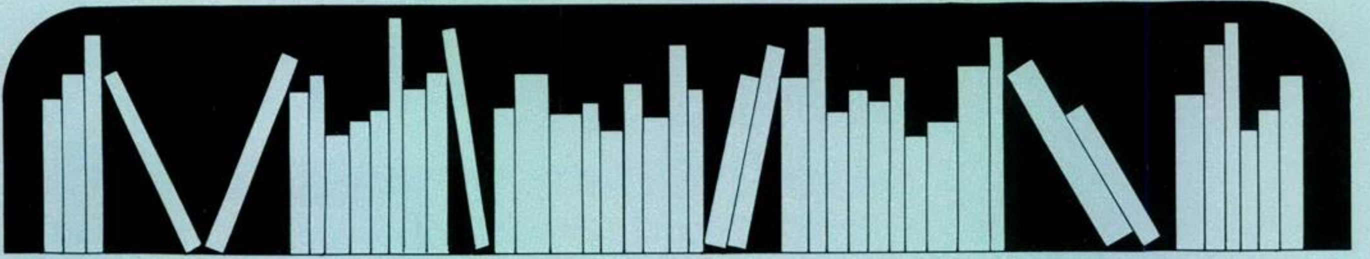

ASTRONOMY REVIEWS

Space, Time and Gravity

by Robert M. Wald

131 pages, hardcover, $10.95
University of Chicago Press (1977)

In the last few years there have been many startling developments in relativistic astronomy. Among them are the prediction of primordial black holes, energy extraction from black holes and particle evaporation from black holes. The lay public has shown considerable interest in these breakthroughs, and as a result several books have been written for them. According to the author, this book is meant to be a brief but clear account of many of these new developments, without oversimplification. Brief it is, and not oversimplified, yet despite its brevity it covers most of the interesting new areas of black hole physics. Unfortunately, the most interesting material is relegated to the last four chapters; the first six are used for laying the foundation. Many of these early chapters are especially brief, and additional material may be needed by some for a complete understanding.

The book begins with a discussion of the geometry of space and time, and continues with chapters on special and general relativity. Cosmology and stellar evolution are the subjects of chapters four to six. All of this is meant as background material; the heart of the book comes in the last four chapters which are concerned primarily with black holes.

These last chapters are the best; chapter 10, in particular, on particle creation near black holes, is excellent. There are few anecdotes and the writing is good. Its approach is about the same level as **Scientific American**.

According to Wald, the book is directed at the general public, but it's unlikely that the casual reader could get through it easily. Mathematical arguments are used; in fact, there are a number of simple differential equations in it. Also, some of the spacetime diagrams may be difficult to understand unless the reader has some background in this area. The author assumes, in addition, that the reader is familiar with such things as the laws of thermodynamics, and the concepts of entropy. By way of comparison, the book is considerably more advanced than, say, Asimov's **The Collapsing Universe**. It's perhaps most appropriate for a college freshman or sophomore science major.

The overall layout of the book is pleasing. Although it is small, the diagrams and print are clear. Wald offers suggestions for further reading, an index, and a few photographs.

For anyone with the proper background and interest, it is indeed an excellent (but brief) introduction. There do not appear to be any errors, and all basic ideas are clearly presented. *Barry Parker.*

* * *

Astronomy: The Cosmic Journey

by William K. Hartmann

536 pages, hardcover, $16.95
Wadsworth Publishing Co., Inc. (1978)

William K. Hartmann, a well-known astronomer and space scientist, has written a new, introductory college level text that joins an already crowded field. With two previous books to his credit (**Moons and Planets**, and **The New Mars**), he is familiar to most readers of ASTRONOMY for his many past contributions to its pages.

This attractively produced volume offers a well-balanced account of basic astronomy within a traditional framework, reminiscent of such classics as Baker's **Astronomy**, but with a fresh and stimulating style of its own. Its overall visual appeal, comprehensiveness, and high accuracy are a credit to both author and publisher. Hartmann has a reputation for an incredibly thorough and conscientious approach to his work, and this is clearly evident to any reader of this book.

The text's 25 chapters are arranged in eight modules that give instructors freedom to select the subject matter they want to teach in the order they want to teach it. Furthermore, this can be done in a totally non-mathematical fashion, for equations are discussed qualitatively in the body of the text and quantitatively in optional boxes. No matter how complex the topic treated, Hartmann's masterful touch makes it both easy and exciting to grasp. As a result, **The Cosmic Journey** makes fascinating reading not only for college students, but also for astronomy enthusiasts and for all who wonder at the night sky.

Hartmann's readers are taken on three simultaneous journeys of exploration — through the historical past, through space and through cosmic time. Topics as diverse as Stonehenge and relativistic cosmology are treated with ease and completeness, and excellent coverage is given the exciting discoveries of space exploration within our solar system. A number of highly effective learning aids complement the text, making these excursions a delight to undertake. An added treat is a number of "Enrichment Essays" at the end of the book dealing with topics of high student interest that seldom find their way into basic astronomy works. One of these, for example, discusses various popular pseudosciences like astrology.

Another highlight of **The Cosmic Journey** is its impressive visual impact upon the reader. The publishers achieved this through an effective mix of unique photographic sequences, duotone reproductions, color plates and even paintings. These last are works done by such well-known space artists as James Hervat, Ron Miller, Adolf Schaller, Chesley Bonestell and the author himself. Hartmann's paintings include some of those that have appeared in past issues of this magazine, as well as many new ones done especially for the book.

One of the best features about **The**

Cosmic Journey is the philosophical spirit it's written in — something sadly lacking in many college textbooks today. The author has made extensive use of quotations from some of the greatest thinkers in astronomy and related disciplines, spanning cultures and time periods.

In summary, **The Cosmic Journey** reads more like a thrilling cosmic adventure story than a dry college textbook, which goes to prove that meaningful education can (and should) be an enjoyable and stimulating experience. There has never been anything quite like Hartmann's masterpiece of exposition before, and you get the feeling while reading it that here is a book that's destined to become a classic. *James Mullaney.*

◆

Guide To Mars

by Patrick Moore

214 pages, hardcover, $9.95
W. W. Norton Co. (1977)

Patrick Moore is one of the most widely read and prolific astronomy authors of the 20th century. Yet after reading this book, one has to wonder how he achieved such a position.

Moore takes a basically chronological approach to our expanding knowledge of Mars over the centuries. He divides the history of the planet's exploration into four periods: 1) prior to 1830, when only rudimentary surface features were known — the polar caps and some dark areas; 2) 1830 to 1877, when Martian maps became moderately accurate and changes began to be noted; 3) 1877 to 1965, when the canal controversy raged and modern Earth based techniques provided information which was thought to be reliable; and 4) 1965 to the present, when robot space probes caused a complete revolution in our understanding of Mars.

Moore deals with the first three periods in great detail. There are some interesting anecdotes. For example, we learn that the experienced and skillful observer J. E. Mellish actually probably saw some of the craters on Mars as early as 1915, while making observations during daylight hours.

Although Moore doesn't mention it, it's incredible that daytime observing of Mars has never become popular with larger telescopes. Yet it was just such a circumstance that allowed the fleeting detail of the craters to be seen. Mellish discovered that Edward Emerson Barnard had seen craters on Mars in 1892-93 with the 36-inch refractor at Lick Observatory. Barnard had not published his results for fear of ridicule. Moore reports that Mellish's drawings were accidently burned and Barnard's have never been found, so the crater testimony is based on written notes alone.

Moore is at his best at this kind of historical anecdote, and the first half of the book dealing with the pre-1965 exploration of Mars contains lots of interesting material. The drawback is that you have to put up with Moore's incessant use of asides: "I must also gloss over...", or "I cannot resist mentioning..." or, even worse, "I hope you will forgive this lengthy digression...". Such a wordy style may be acceptable to his British readers, but sounds stuffy to many American readers.

We could live with these occasional lapses, but the book is much more seriously flawed where it deals with the Mariner and Viking results. The chapter on the Viking results briefly describes the three biology experiments in the two landing craft and their somewhat ambiguous findings. However, Moore doesn't mention the fact that the mass spectrometers onboard failed to find organic compounds in the Martian soil, down to a detectability of one part per billion. This was a pivotal finding that led the way to current speculation that the biology experiments' results were probably mimicking life processes. Chemical reactions rather than reactions of living organisms seem to be the best explanation in view of the apparent absence of organics. Moore's omission of this point is an inexcusable blunder.

But there's more. In the next chapter he correctly states that the channels on Mars were carved by a flowing liquid — most likely water. But he then says, "If the riverbeds were extremely ancient by geological standards, that is to say, millions of years old — they would hardly have been preserved to the extent that they actually are. Erosion would have taken its toll." From this he concludes that the riverbeds are relatively young: "In all probability we are reckoning in tens of thousands of years rather than millions." Moore even admits that some of them have craters inside them, and yet he still insists they are youthful features.

It appears Moore has simply ignored or doesn't know about the analysis of the Viking and Mariner orbital photos of the Martian channels that reveal crater densities sufficient to make them at least millions of years old and possibly billions. He uses this ill-conceived assumption to flog his pet theory that the Martian craters — the larger ones anyway — are volcanic in origin rather than caused by impacts of asteroidal objects.

The chapter on Phobos and Deimos, Mars' moons, provides another example of a preconceived notion being used to explain phenomena, even where contrary to physical possibility. Moore proposes that the craters on Phobos "could well be of internal origin: blowholes perhaps". Such a statement is sheer nonsense. There is no conceivable mechanism to provide the internal heat necessary to generate the blemishes on Phobos. They are caused by impacts of celestial debris, and to suggest the reverse is misleading the reader inexcusably.

The final chapter, entitled "Mars in the Future", is a dull speculative essay that makes the 1956 Walt Disney film production on the exploration of Mars seem modern. Better material can be found almost anywhere.

This book fails completely in dealing with contemporary aspects of our knowledge of Mars. Although the historical sections seem factually correct and contain some interesting anecdotes, there is virtually nothing in this book that has not been presented better elsewhere. *Terence Dickinson.*

◆

NEW ASTRO-BOOKS

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by John H. Mallas and Evered Kreimer

248 pages (illus.), hardcover, $9.50
Sky Publishing (1978)

Ten years ago two amateur observers published a survey of the Messier list from a visual and photographic standpoint. This book reprints their survey, adding historical background material on Messier (including a facsimile of his final published list), and a 32 page section of color photographs.

Positional Astronomy and Astro-Navigation Made Easy

by H. R. Mills

267 pages (illus.), hardcover, $22.50
John Wiley (1978)

Subtitled "a new approach using the pocket calculator," this book by an experienced navigator and instructor of astronomy shows how you can tackle many apparently complex problems with little effort, using a calculator. Details on construction of sundials are also given.

Worlds Beyond: The Everlasting Frontier

edited by L. Geis and F. Florin

301 pages (illus.), paperback, $6.95
And/Or Press (1978)

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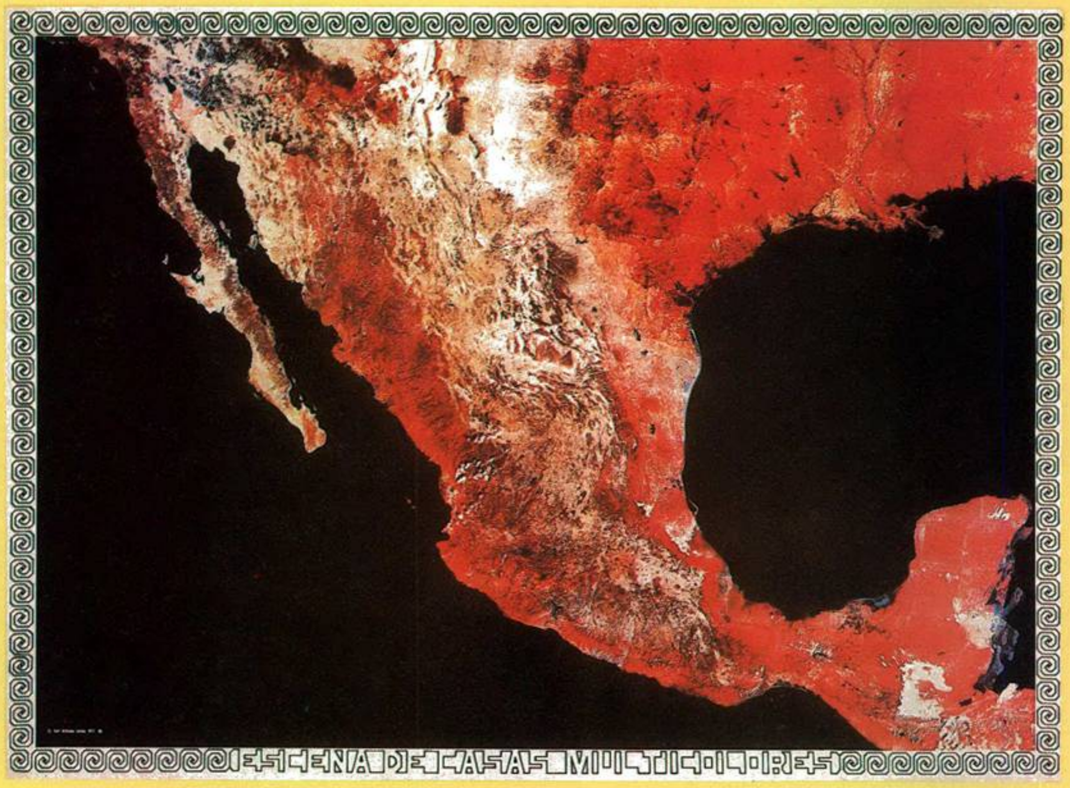

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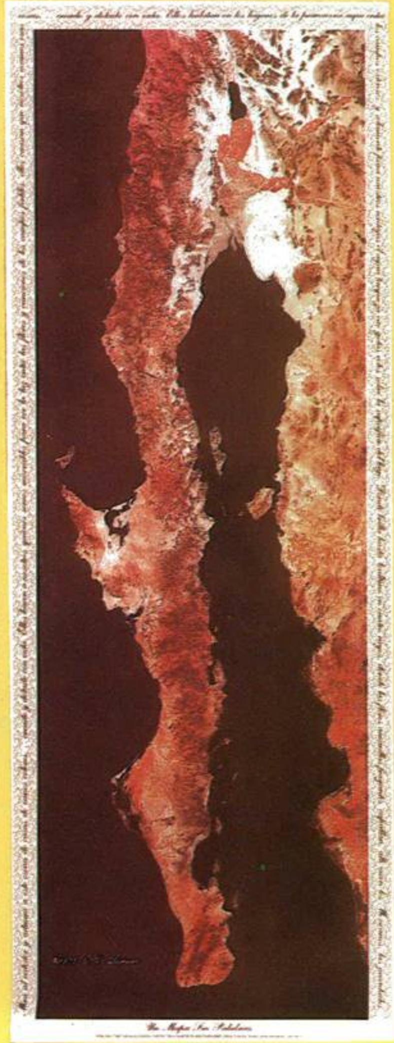

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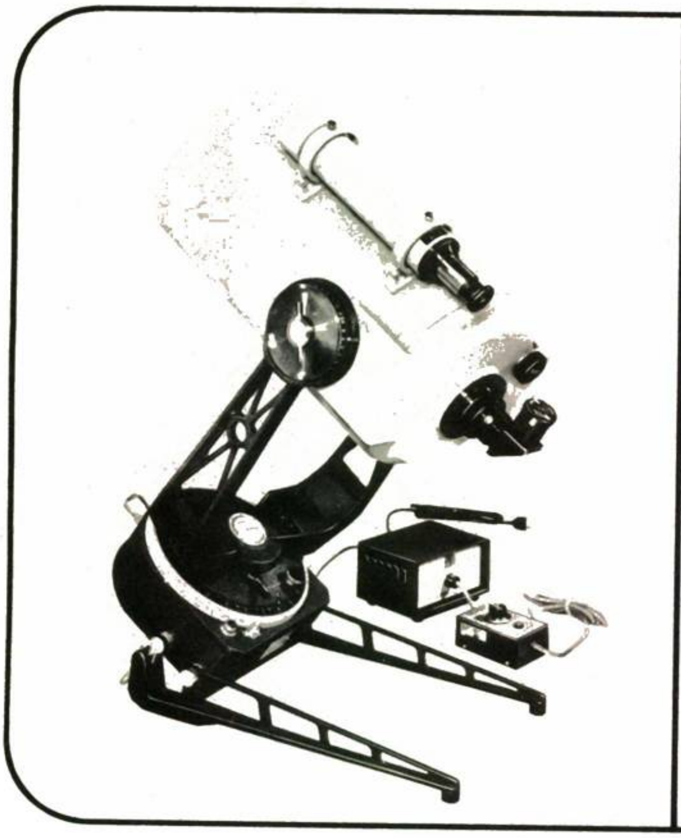

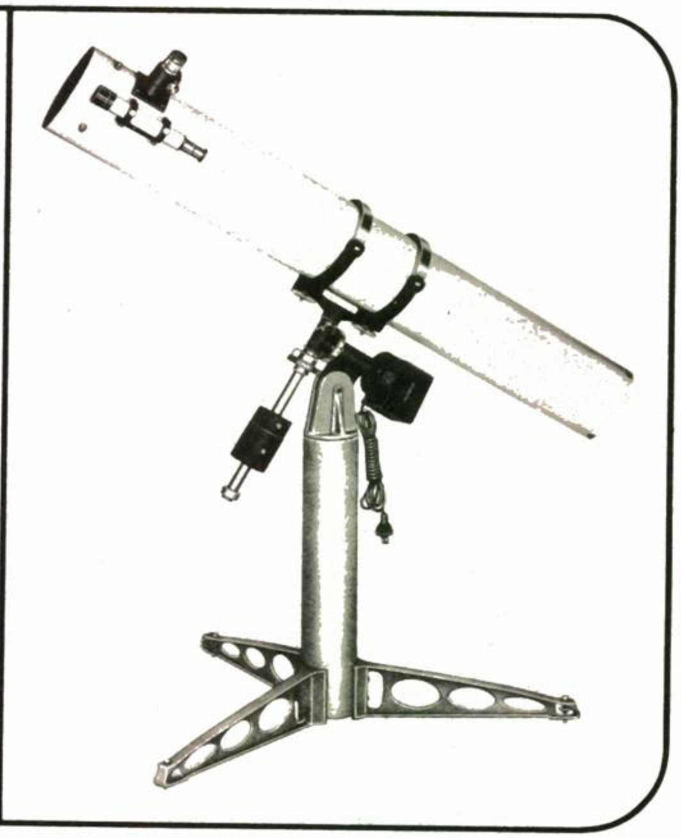

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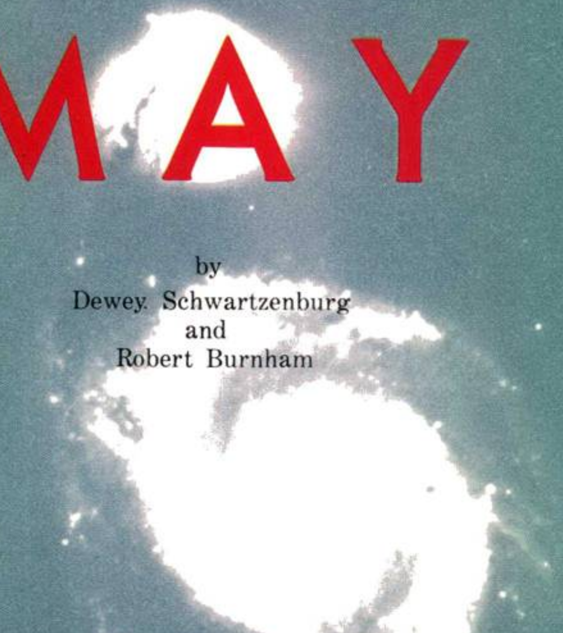
STAR DOME



MAY

by
Dewey Schwartzenburg
and
Robert Burnham

Until Galileo turned his tiny, primitive glass on the sky only a few hundred years ago, all astronomy was based on naked-eye observations. The great works of Hipparchus, Ptolemy, and Copernicus were done without the aid of so much as a pair of binoculars, and even Kepler's achievement in formulating the laws of planetary motion depended on the careful, but unaided, observations of Tycho Brahe. Unaided by telescopes, that is, but it's also true that Brahe had at his disposal a wide array of precise astronomical instruments for the accurate determination of celestial position.

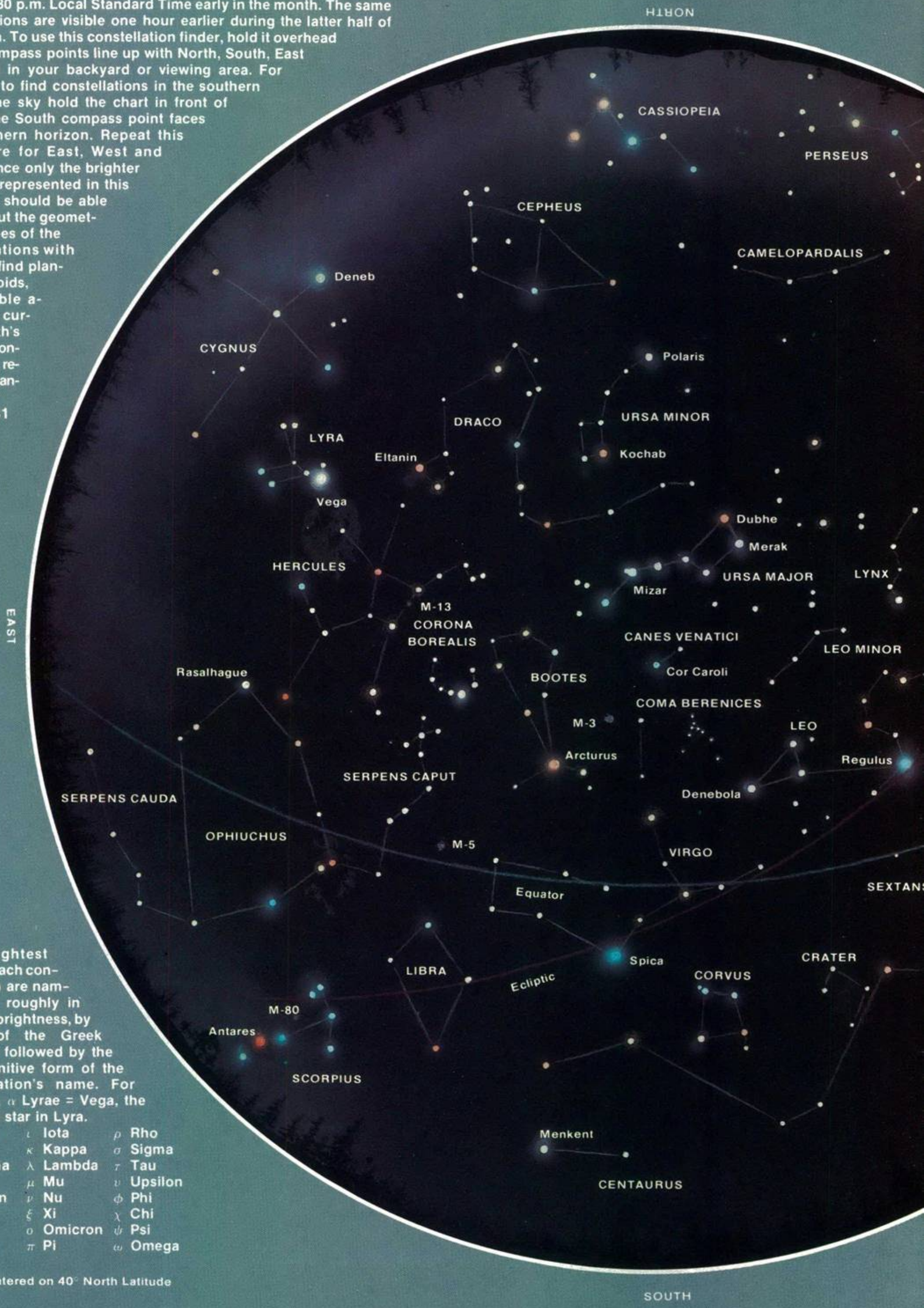
It can be surprising to modern astronomers, amateur and professional alike, how sophisticated astronomy managed to be without what is now considered to be the most basic of all astronomical instruments — the telescope. While it is true that the science of astronomy was inextricably mixed up with religion, superstition, and astrology, especially in ancient times, many useful and accurate discoveries were made. And the greatest of the ancients, such as Hipparchus and Ptolemy, were notably free of superstitious attitudes, and in their astronomy approached the study of the heavens with an almost modern stance (although it must be admitted that Ptolemy did deal with astrology with as much seriousness as astronomy).

Claudius Ptolemy, who worked during the first part of the second century A.D., is generally considered the greatest astronomer of ancient times, though he certainly drew on the work of his predecessors. His most famous work is the **He Mathematike Syntaxis** — "Mathematical Treatises" — which contains a summary of astronomical knowledge as well as the mathematical systems for calculating the motions of the planets.

The greatness of Ptolemy's work has been challenged recently by Robert R. Newton of the Applied Physics Laboratory of Johns Hopkins University. In his book **The Crime of Claudius Ptolemy**, Newton charges the famed ancient astronomer with fraud. He claims that Ptolemy could never have made the observations on which he bases his theories, because the instruments he used were simply not capable of such accuracy. In the cases where Ptolemy's measurements are inaccurate, on the other hand, Newton claims that Ptolemy could not have been so much in error. His conclusion is that Ptolemy deliberately falsified observations, and was the most successful charlatan in the history of science — having fooled not only his contemporaries but also his successors for centuries into the future.

Historians of science, however, remain rather skeptical of Newton's thesis, and most recently Noel M. Swerdlow of the University of Chicago

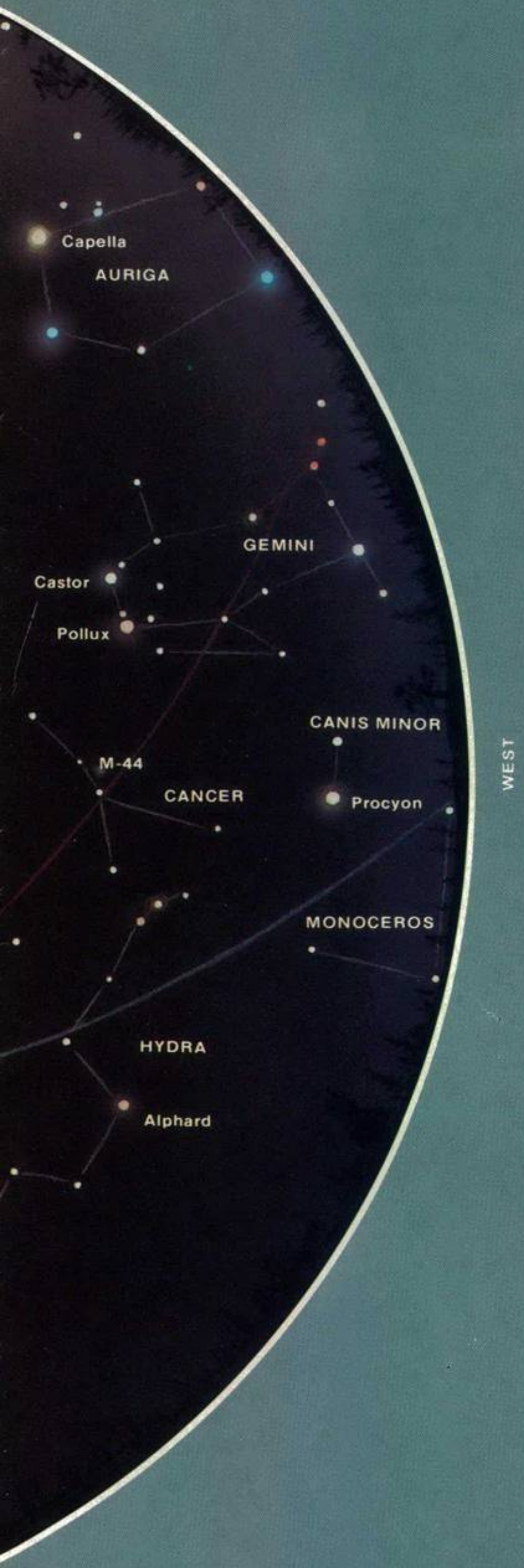
This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 31


NORTH
CASSIOPEIA
PERSEUS
CEPHEUS
CAMELOPARDALIS
Deneb
CYGNUS
Polaris
URSA MINOR
DRACO
LYRA
Eltanin
Kochab
Vega
Dubhe
Merak
HERCULES
URSA MAJOR
LYNX
Mizar
EAST
M-13
CORONA BOREALIS
CANES VENATICI
LEO MINOR
Rasalhague
BOOTES
Cor Caroli
COMA BERENICES
M-3
LEO
Arcturus
Regulus
SERPENS CAPUT
SERPENS CAUDA
Denebola
OPHIUCHUS
M-5
VIRGO
SEXTAN
Equator
Spica
CRATER
LIBRA
Ecliptic
CORVUS
M-80
Antares
SCORPIUS
Menkent
CENTAURUS
SOUTH

The brightest stars in each constellation are named, very roughly in order of brightness, by letters of the Greek alphabet followed by the Latin genitive form of the constellation's name. For example, α Lyrae = Vega, the brightest star in Lyra.

α Alpha
β Beta
γ Gamma
δ Delta
ε Epsilon
ζ Zeta
η Eta
θ Theta
ι Iota
κ Kappa
λ Lambda
μ Mu
ν Nu
ξ Xi
ο Omicron
π Pi
ρ Rho
σ Sigma
τ Tau
υ Upsilon
φ Phi
χ Chi
ψ Psi
ω Omega

Map Centered on 40° North Latitude



Map by Adolf Schaller

has pointed out serious errors in the statistical analysis on which Newton based his charges. It seems Ptolemy's reputation, even after all these centuries, will remain untarnished.

And his reputation is indeed great. The scholars who succeeded Ptolemy took to calling his work the "Megale" ("Great"), or even the "Megiste ("Greatest") Mathematical Treatises." With the collapse of Western civilization in the fall of the Roman Empire, his work survived among the Arab scholars, who referred to it as the **Almagest** — by which it has been known ever since. ("Al" is Arabic for "the," so "Almagest" means simply "The Greatest.")

Because Western civilization is the dominant culture on Earth today, we tend to lose sight of the fact that this has not always been so, and that the history of the world is much larger than the history of the West. Learning and culture did not die out altogether in the mis-named "Dark Ages" of Europe: during that period there was a brilliant, sophisticated, flourishing civilization under the umbrella of Islam — a civilization which spread, at its height, from Spain to India. Yet Westerners know almost nothing about that society's history and culture, myopically viewing only the history of western Europe as significant during that time.

In astronomy, though, we are reminded continually of the long period of Islamic ascendancy in our science. Aside from the few in Greek and Latin, virtually all the stars which have proper names have Arabic names. In part, this is because of the great attention the Arabs gave to individual stars, while the ancient Greeks and medieval Christians focused on the *patterns* formed by stars — the constellations. Thus, when the body of Ptolemy's work re-entered the stream of Western culture (in the twelfth century), it brought along with it the names of the stars in Arabic.

Now and then some misguided soul, obsessed with the "superiority" of western culture and offended by all the "barbarisms" in the star catalogs, would attempt to replace the traditional names with western, Christian substitutes. All such attempts at bowdlerizing the stars happily failed, however, and though the ancient names have been supplanted by modern scientific notation to a degree, they remain valid for everyday use. On the close-up map each month in Star Dome, we include the proper names of those stars in the constellation which have a proper name, for those of you who wish to learn them. The best source for the names of stars is the classic **Star Names: Their Lore and Meaning**, by Richard Hinckley Allen (available from ASTRONOMY).

Not only does Allen give the Arabic names, but all other names by which stars have been known in other cultures, including the Chinese. Where the meaning of the name is known, that too is given, and thus we learn that Fomalhaut means "the fish's mouth," Deneb "the tail," Rigel "the leg," and Dubhe "the bear."

When we look up at the stars today and recite the litany of their names, we stand in a tradition of worldwide human culture reaching back through the glittering palaces and sophisticated observatories of the Islamic empires to the wandering nomads of the Arabian deserts, who gazed up at the night sky above their tents and called the stars by name.

Close-Up

Canes Venatici

Canes Venatici, the Hunting Dogs, are figures in a constellation of relatively recent manufacture. They were placed in the sky under the handle of the Big Dipper in 1690 by the Danzig astronomer Johannes Hewelke, who's better known by the Latin form of his name: Hevelius. They represent Bootes the herdsman's dogs, Asterion and Chara, which are chasing the Great Bear (Ursa Major) around the pole. The usual representation you see on old star maps is one of two lean greyhounds straining after the bear.

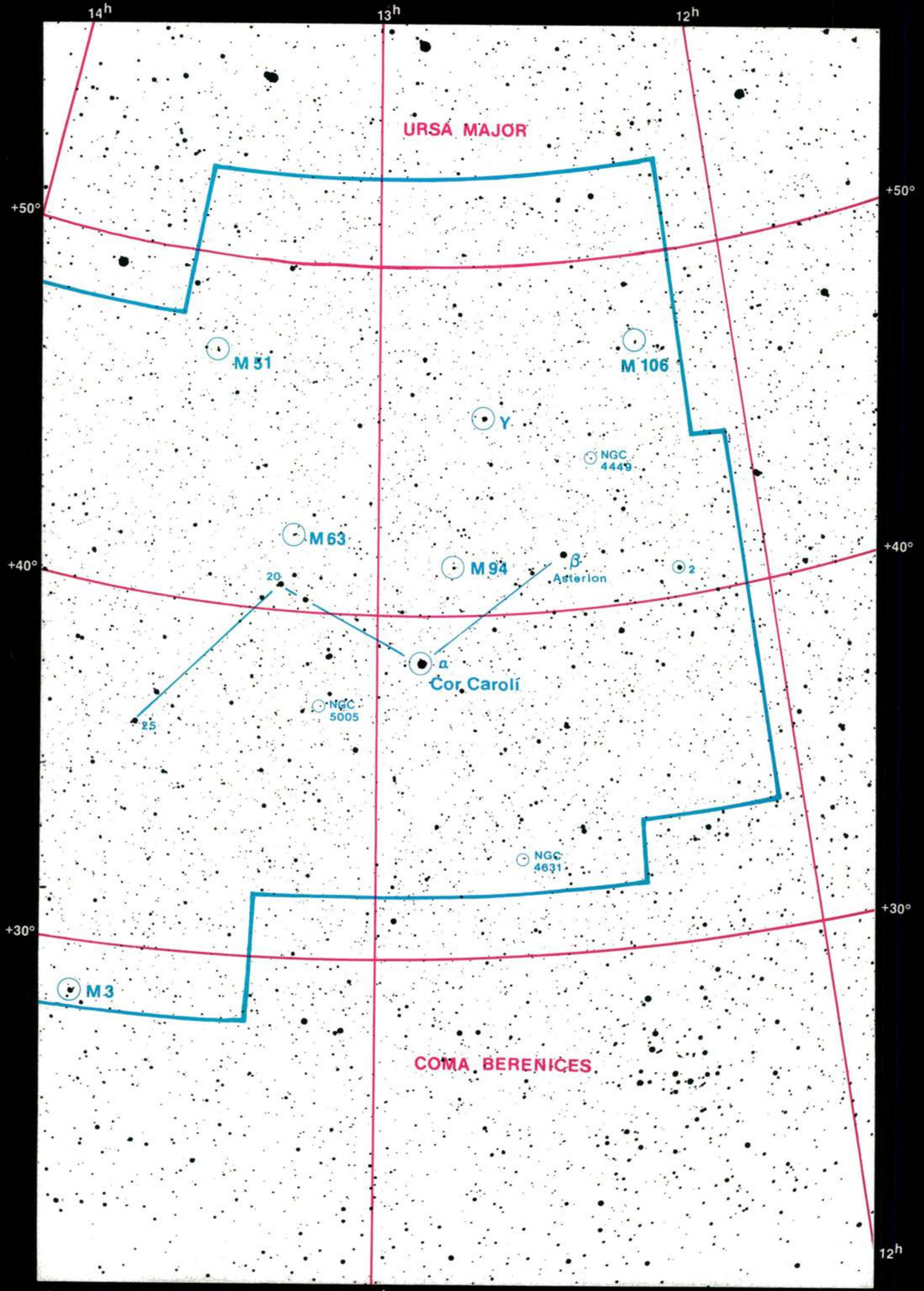
To the naked eye, the region is rather dim, which explains its late incorporation into the roster of constellations. There's only one brightish star, Alpha (α), followed by a number of lesser ones down to the limit for visibility. What, then, makes the region of any interest at all?

Hevelius had no inkling when he laid out the constellation, but it so happens that his "new" constellation abounds in galaxies, many of which are outlying members of the well-known cluster in Coma Berenices to the south. This seemingly dim region of sky actually offers a great richness of fine, distant objects for observers. No one knew of this wealth, of course, until telescopes had swept the area. As you'd expect, it was the ubiquitous Charles Messier who first began to record and describe them, although Messier himself was not aware that he was observing great whirlpools of stars in the depths of space. He listed five objects here, all worthy of inspection with amateur instruments.

Nor, as we'll see, are galaxies the only attractions. Canes Venatici also offers several fine doubles, a variable, and a magnificent globular cluster near the southern boundary. Let's

Epoch 1950 coordinates

CANES VENATICI


14h
13h
12h
URSA MAJOR
+50°
+50°
M 51
M 106
Y
NGC 4449
M 63
+40°
+40°
M 94
β
Asterion
2
20
α
Cor Caroli
NGC 5005
25
NGC 4631
+30°
+30°
M 3
COMA BERENICES
12h
13h

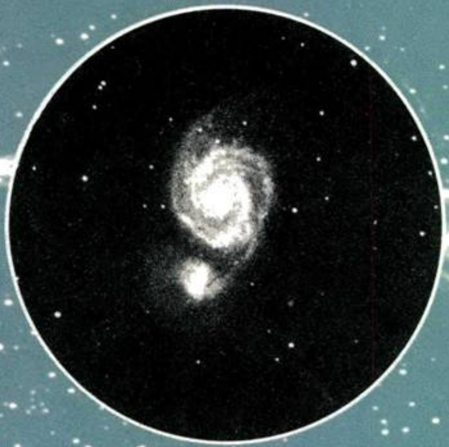
Map by Dewey Schwartzenburg

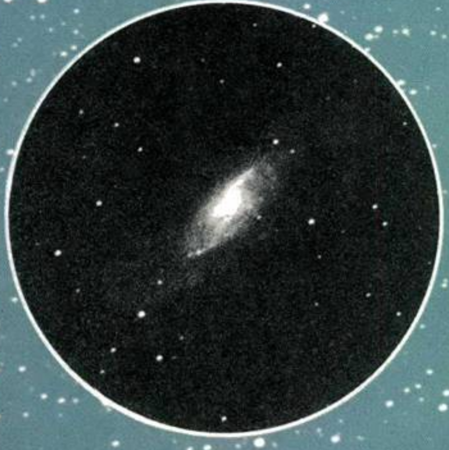
Photograph by Robert Provin and Brad Wallis begin this month's Close-Up with one of these fine double stars.

Cor Caroli

Cor Caroli is the name given to Alpha (α) CVn, the brightest star in the group. The star's two components are of 2.8 and 5.4 magnitude, summing to a combined magnitude of 2.7. The system lies at a distance from us of about 130 light-years, and the components' apparent angular separation (20″) gives a true distance between them of 1/80th of a light-year, or somewhat less than 800 astronomical units.

The earliest reliable measurements of the stars' relative positions began in the 1830s, but very little motion has been detected since. However, because both components share a common proper motion and direction, they must be physically associated in some way. Patrick Moore, perhaps simply to be different, thinks the pair is an optical double, that is, a mere happenstance of two stars being close to each other in the line of sight.





Two of the spiral galaxies featured in this month's Close-Up are seen above in photographs made with a 12½-inch reflector. Top: The famous Whirlpool Nebula, M-51, is easily visible in even the smallest telescope, though large apertures are needed to make out the spiral form which gave rise to its name. Bottom: Although larger than M-51, M-106 is a little dimmer and its structure is more difficult to make out. Two other much fainter galaxies are barely discernable in this 20 minute exposure. Photos by Jack Newton.

Robert Burnham, Jr. mentions in his **Celestial Handbook** that when astronomers measured the actual space motion (in 3 dimensions), the result led them to believe that Cor Caroli may well be part of the stream of stars in Taurus to which the Hyades Cluster belongs.

In any case, this a splendid little pair whose components are both a brilliant white, as befits their spectral classification of A0. Past observers have gone to great lengths to describe subtle differences in the tints, but for the most part, these observations are suspect both due to the telescopes they were using (refractors, usually, with their attendant coloration), and perhaps also to the contrast in brightness between the two stars.

The name of the star means Charles' Heart and was supposedly given to it in 1725 by Edmond Halley (of comet fame) to commemorate King Charles I, who was executed in 1649. But you'll find (if you research it) that this account is a late one, and Burnham mentions that the name, originally Cor Caroli Regis Martyris, probably dates back to the time of Charles I's execution, but never had wide popular circulation before 1660 (when the monarchy was restored) for obvious political reasons, and so the late-origin theory arose.

M-94

About 2½° to the north-northwest of Cor Caroli lies a pretty spiral galaxy, M-94. Although it bears an "M" number, the actual discovery was by Messier's rival in comet-hunting, Pierre Mechain, on the 22nd of March, 1781. (Messier was not a claim-grabber, however. Unlike some scientists of his time, he took care to note Mechain's priority in the entry for his list.)

M-94 is a diffuse round glow, slightly oval, with a bright central spot, measuring overall about 4 minutes of arc by 5. The integrated magnitude is 7.9, which should make it a relatively easy object to see at low powers. Some galaxies and nebulae are bright, but their light is spread over a large area. The surface brightness (which is what counts for easy detection) can then be very low, and the object very hard to see.

Observers in the past have often remarked on how cometlike the nucleus of M-94 appears. Smyth noted this, and then rather presciently guessed that it might be a tight cluster of stars. Webb notes that the Earl of Rosse saw spiral structure in it, which is certainly possible. Photographs show two main arms trailing in a direction that indicates a clockwise rotation. If you have a good scope and really dark skies, you might be able to pick up a hint or two of the arms yourself.

Astronomers have classified M-94 as an Sb galaxy, a type that has spiral arms which are distinct, yet not very loose or extended. Its near circularity says that you're seeing the galaxy almost face-on. The Sb galaxies also have relatively large and amorphous nuclei, a fact your telescope will show.

Y CVn

Continue to the northwest of M-94 a distance of about 5° and you'll arrive at a ruddy little star that's very distinctive: Y CVn. Y is a semi-regular variable with a period of about 158 days. At times of maximum light, its brightness is 4.8, while the minimum light is about a magnitude and a half fainter. The star is very red,

Selected Objects — Canes Venatici

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950) Dec.	
2	★²	5.8/8.9	11.5″	12^h14^m	+40°56′
*M-106	§S	8.9	20′ x7′	12^h17^m	+47°35′
NGC-4449	§#	9.2	4′ x3′	12^h26^m	+44°22′
NGC-4631	§S	9.3	13′ x2′	12^h40^m	+32°49′
* Y	m★	8.2-10.0	158^d	12^h43^m	+45°43′
* M-94	§S	7.9	5′ x4′	12^h49^m	+41°23′
* Cor Caroli (α)	★²	5.4/2.8	20″	12^h54^m	+38°35′
NGC-5005	§S	9.8	4′ x2′	13^h09^m	+37°19′
* M-63	§S	9.5	10′ x5′	13^h14^m	+42°17′
* M-51	§S	8.1	10′ x6′	13^h28^m	+47°27′
* M-3	●	6.4	10′	13^h40^m	+28°38′

* Detailed in Close-Up

★² = Double Star
§S = Spiral Galaxy
§# = Irregular Galaxy
m★ = Regular Variable
● = Globular Cluster

so much so that while it's visible to the naked eye, a photograph made in blue light shows it remarkably faint at magnitude 9.

Stars like this are known as "carbon" stars, so-called for the great abundance of that element in their spectra. These stars have such cool outer atmospheres that many elements and even molecules are found there. R Leporis, a red star in Lepus (the Hare, below Orion), is the prototypical example of these cool stars. Y has a surface temperature of about 2600° Kelvin, so cool that it's scarcely "lit" as a star, and as ruddy as the glow of a terrestrial fireplace. Burnham mentions that there's no distance yet determined for Y, so we're in some doubt as to the physical size of the star. But if we can judge from others of its kind, it's likely to be about as large as Mira Ceti, a giant long-period variable familiar to many observers.

In the past few years, it's shown some remarkably erratic variations, so try following it for several weeks to see what changes you can detect in its behavior.

M-106

Moving still further to the west-northwest again about 5°, you come to another galaxy, known originally as NGC-4258 and more recently as M-106. M-106 is one of the "addenda" Messier objects, that is, ones not part of M. Messier's final published list of 103 objects. The addenda were compiled later by astronomers on the basis of notes and observations left unpublished. Helen S. Hogg added M-106 in 1947 (along with M-105 and 107) when she found mention of them in a letter from Mechain to Messier. Kenneth Glyn Jones refused to include M-106 in his book on the Messier list, saying "the trouble with this sort of thing is to know where to stop...," but most subsequent compilers have included it.

The galaxy is another spiral of type Sb. From our vantage point in space, it is seen at an angle of about 25° from edge-on, rather like M-31 in Andromeda. In a small telescope it looks like an elongated hazy patch about 20 minutes of arc by 7, with the long axis being in a NW-SE direction. The nucleus looks large and bright; the galaxy as a whole has an integrated light of 8.9 magnitudes.

Photographs show dust lanes galore in the disk and across the nucleus, so if you have a chance to look through a medium or large instrument, try to see the lanes using moderate or high powers on a very dark night. This galaxy's two main spiral arms are relatively bright and, under superb skies, you may see them as extensions at each end of the disk.

M-51

The Whirlpool Galaxy is easily one of the classiest deep-sky objects for any telescope owner. Even a small instrument clearly shows something exciting is happening here. Look for it about 3° to the southwest of Alkaid, the star at the end of the Big Dipper's handle. Another way to find it is to center Cor Caroli in your widest-field eyepiece. Then moving your scope 9° to the north and about 5° to the east should put M-51 into your field of view.

The angular extent of the galaxy itself (not counting the companion NGC-5195, 4 arc minutes to the north) is about 7 minutes of arc by 11, and its total magnitude is 8.1. NGC-5195 measures 2 minutes by 3, and is at magnitude 9.7. In form, M-51 is a spiral galaxy of type Sc, a type characterized by well-developed arms and a small nucleus. M-51 has a "normal" nucleus, that is, one that's relatively small.

NGC-5195 is an amorphous mass of light, and has no particular structure to it: Sandage classes it as an irregular of the M-82 type, which is odd because M-82 was formerly thought of as a large, violently eruptive galaxy. M-82 is now believed to be a galaxy undergoing vigorous star formation due to an encounter with interstellar dust, and NGC-5195 a galaxy strongly disrupted by a near collision with M-51. These interpretations are, of course, subject to change.

M-51 was also the first galaxy ever to have spiral structure seen in it (by the Earl of Rosse with his 6-foot speculum-mirror telescope in 1845). Depending on the size of your instrument, you may detect what you think is spiral structure (or at least hints of it), but be careful. You'll need a very dark sky and a large instrument: 10" or bigger. Keep the magnifications you use as low as practical, for the object can't stand "over-magnification" well. Practice and experience will probably help a lot, too, since you'll find it hard to be sure you aren't just seeing what photographs have told you to expect.

In a 6" scope, the nucleus stands out clearly, surrounded by the pale glow of the disk. Webb claimed that with a 9½" mirror, he could make out traces of the arm extending over to NGC-5195. Furthermore, he and several other observers have reported seeing either a granulated or knotty appearance to the nucleus and disk. What do you find?

M-63

About halfway between M-51 and Cor Caroli, and lying slightly to the east of a line connecting the two, you'll find another attractive spiral, M-63. This galaxy is also type Sb (similar to M-106), and since you're seeing it at approximately the same angle of view, it will also look oval. Pierre Mechain discovered it in 1779, so we're celebrating its "bicentennial" this year.

The galaxy measures 5 minutes of arc by 10, and is at magnitude 9.5. The visual appearance is of an elongated hazy patch with a nucleus that's extended and somewhat mottled. The position of the long axis is almost east-west. John Mallas, using a 4" refractor, saw the nucleus as grainy and strongly brighter than the disk, which seems to be a common observation with most instruments not big enough to make out any details. Test your estimates of the galaxy's brightness by comparing it with the 8th magnitude star that you'll see in the field about 3½ minutes of arc to the west-northwest.

As with many galaxies, the low surface brightness means that high powers won't help much, so keep to the low-power end of your eyepiece assortment if you want best results.

M-3

In wrapping up this month's tour, we'll change the pace a bit and go hunting for a globular cluster.

About halfway between Cor Caroli and Arcturus, your finder scope or binoculars will reveal the splendid cluster, M-3. Discovered by Messier on May 3rd, 1764, it may well be the finest example of its kind in the northern sky. It is certainly the rival of M-13, and a careful comparison around midnight (when both will be visible on May evenings) may settle the matter in *your* mind if not in the minds of each object's boosters.

The integrated magnitude of the group is 6.4, and it spans a diameter of 10 arc minutes. M-3 looks very round and bright through the scope, and with moderate powers begins to break up into stars around the edges. Smyth, whose enthusiasm got the better of him at times, reported that its uneven stellar distribution made it look like a jellyfish, a *Medusa pelluceus* in his words, but few observers since have seen this. Most people see the overall distribution of stars as being very smooth and slightly granular, except toward the edges where the resolution into individual stars begins. There may be a slight hint of star-strings across the ball, but the effect is very subtle.

The current estimate for cluster members includes over 45,000 stars, with the proportion of variable stars being higher here than in any other globular. Its mass is estimated to be equal to about 245,000 suns. Because this cluster is so bright and large, it, along with M-5 (in Serpens) and M-13 (in Hercules), have been studied carefully to construct color-magnitude diagrams. These reveal that the cluster is something like 10 billion years old. It is, perhaps, asking too much that we comprehend something that's been around twice as long as our Sun and its retinue of planets.

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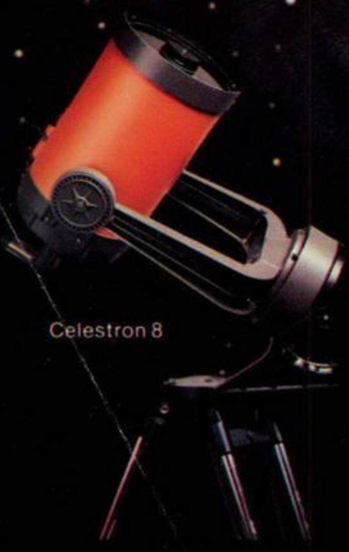

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